JPRS-UES-91-005
19 AUGUST 1991

JPRS Report

Science & Technology

USSR: Earth Sciences

Science & Technology
USSR: Earth Sciences

JPRS-UES-91-005 19 August 1991

CONTENTS

Ecology

The Arctic's "Black Gold"

917N0129A Moscow ZEMLYA I VSELENNAYA in Russian No 1, Jan-Feb 91 pp 9-15

[Article by Doctor of Geological-Mineralogical Sciences V. P. Gavrilov, Moscow Petroleum and Gas Institute imeni I. M. Gubkin]

[Text] Thus far, development of power engineering has depended in many ways on oil and combustible gas: These hydrocarbon compounds now provide for 70 percent of the world's energy consumption. Will these resources hold us over until mankind is able to find an alternative source of energy, one that is just as abundant, and ecologically clean as well? The reserves of crude hydrocarbons are finite, after all. And specialists believe that we are already quite close to exhausting the contents of our "oil well." This is why oilmen are drilling the Earth in the sweltering deserts, in the humid tropics, and even in the mountains. The open-work structure of the drilling rig has become an inseparable part of the panorama of many seas of the world ocean. Oilmen are even making their way to the top of the world, covered by an ice layer many meters thick. What are the prospects for developing the oil- and gas-bearing subsoil of the Arctic? What progress is being made, and what is it costing? These questions are answered in the article below, written by Professor V. P. Gavrilov, a well known specialist in the development of oil and gas resources of the USSR's continental shelf.

Like an Oil-Soaked Sponge

Discovery of a giant oil deposit in 1968 on the northern Alaskan shore of the Beaufort Sea was the starting bell of Arctic oil development. Many years of fruitless prospecting in the vicinity of the Alaskan Peninsula made American specialists pessimistic about oil. The last hole, costing around $10 million, was being drilled when a heavy flow of oil was struck at a depth of 2.5 km (the deposit was concentrated in the subsoil of the peninsula, but part of it also extended beneath the Beaufort Sea). It was then that the oil derricks marched out into the Arctic Ocean. Ten years after discovery of the deposit at Prudhoe Bay, which American oilmen named the "discovery of the century," its exploitation began. As early as 1976, annual extraction approached 80 million tons. Now this is an important source of oil for the USA: Just in the last decade of exploitation, the deposit provided the country with an income of $100 billion. Later on, specialists—and not just Americans—came to realize that the Arctic subsoil is like a porous sponge soaked with oil and gas.

The main difficulties in developing the Arctic are the severe climate and the thick carapace of ice. Even the southernmost edge of the Barents Sea, to which the Gulf Stream reaches, does not freeze year- round, but even here, strong north winds rage. There are a few things to ponder before starting to develop the mineral resources of this region. The question that arises is this: Is it all worth it?

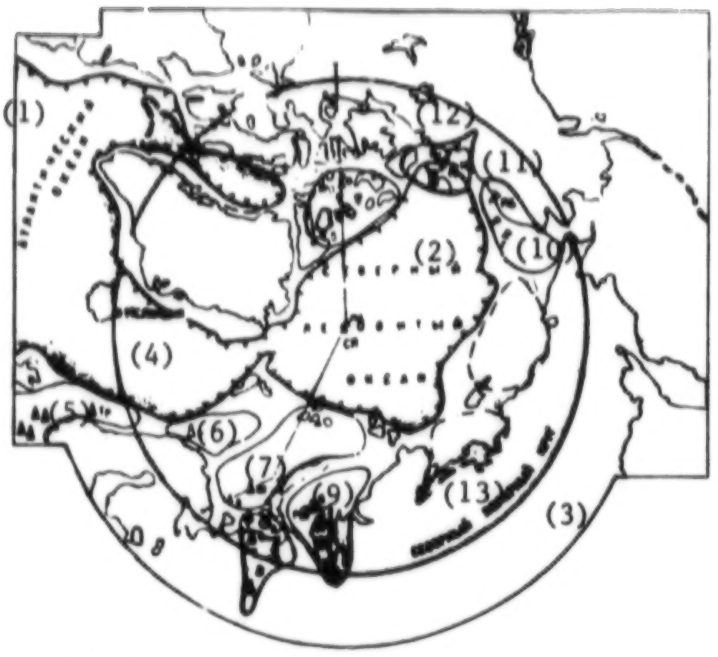
From the standpoint of geological structure, the Arctic consists of the submerged margins of Eurasia and North America, which encircle the deep basins of the Arctic Ocean. The submerged continental margins are made up in part of the continental shelf, which is where explorations are presently under way. The shelf regions are a part of the continents: They dropped beneath the sea just 10,000-15,000 years ago, when huge glaciers melted and the coastal plains of the continents found themselves under water. The subsoil of the shelf consists of a layer of sedimentary rock attaining a thickness of 20 km in places (at the Barents Sea). The sedimentary layer does not form a continuous blanket; instead, it consists of individual "spots" hundreds of kilometers across. The porous layers of this uniquely structured sedimentary mantle can be saturated with oil and gas. Specialists refer to them as **oil and gas basins.**

Oil and Gas Basins

Around a dozen oil and gas basins can be distinguished in the Arctic. One of the largest is the **North Sea** basin, which is contiguous with the Arctic seas. It is a huge bowl-shaped downwarping with an area of 660 km^2, filled with a 10-kilometer layer of sediments. The first gas deposit was discovered here in 1965, and by now, as many as approximately 200 oil and gas deposits have been discovered. The total hydrocarbon potential of the sea (together with contiguous land) is estimated at 13.5 billion tons, with the bulk of this wealth being in territorial waters of Great Britain and Norway. The best-known deposits of this basin are **Ekofisk, Eldfisk, Brent, Statfjord** and **Oseberg**. Oil deposits are being discovered at depths of 2.5-3 km. High well yields are typical—up to 3,500 tons per day. The Troll gas giant, with reserves of more than 1.5 trillion m^3, was discovered in waters of the Norwegian Sea in 1979. The future gas supply of all Western Europe is associated with its development. In recent years, over 170 million tons of oil and around 200 billion m^3 of gas have been extracted annually from the North Sea.

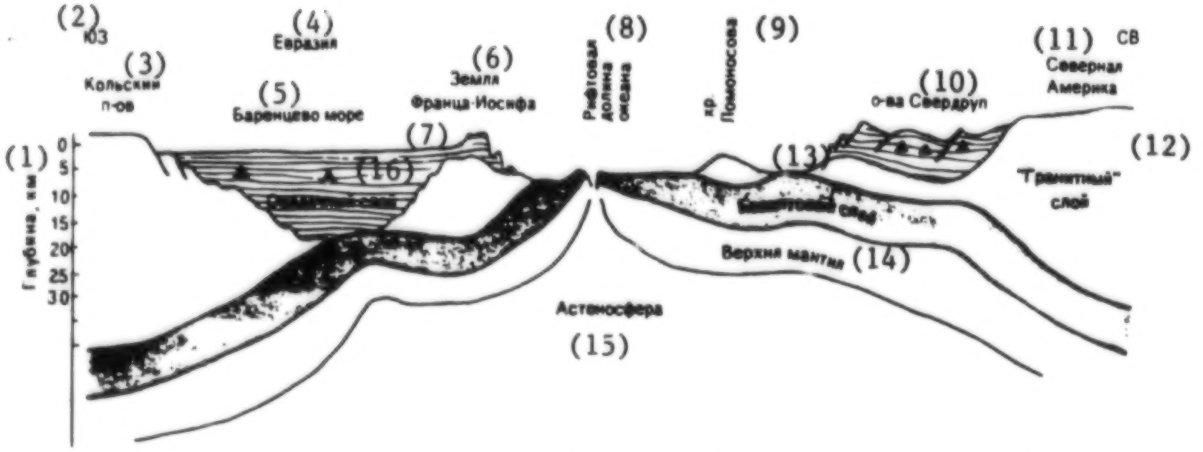
The **Norwegian** oil and gas basin, which embraces the Norwegian and the western part of the Barents Sea, lies east of the North Sea basin, within the bounds of the Arctic proper. Explorations began here in 1980, and they led to the discovery of several gas deposits (**Tromso, Kheydrun** [transliteration] and others).

A large part of the Barents Sea and the northern regions of the Kara Sea make up the huge **East Barents Sea** oil and gas basin. This is a vast downwarping with an area of up to 800,000 km^2, in which the thickness of sedimentary layers exceeds 20 km. High hopes for the future are associated with this basin. But although explorations have already been going on for 10 years, our geological knowledge of the Barents Sea remains rather low. Nonetheless, marine oilmen have managed to discover a number of gas deposits during this time (**Murmanskoye, Severo-Kildinskoye**). The giant **Shtokmanovskoye** gas-condensate deposit was discovered in the central part of the sea in 1988, 600 km north of the Kola Peninsula.



Arctic Oil and Gas Basins (Blue). Broken lines indicate possible oil and gas basins. Several large deposits are marked on the map [see Key]. Filled triangles—oil; empty triangles—gas. The outer boundary of the Arctic shelf is marked in brown.

Key: 1—Atlantic Ocean. 2—Arctic Ocean. 3—Polar Circle. 4—Iceland. 5—Troll. 6—Tromso. 7—Shtokmanovskoye. 8—Leningradskoye. 9—Rusonovskoye. 10—Prudhoe Bay. 11—Kopanoar. 12—Koakoak. 13—Olenekskoye



Geological Cross Section Through Arctic Subsoil. Filled triangles—oil or gas deposits

Key: 1—Depth, km. 2—South. 3—Kola Peninsula. 4—Eurasia. 5—Barents Sea. 6—Franz Josef Land. 8—Oceanic Rift Valley. 9—Lomonosov Ridge. 10—Sverdrup Islands. 11—North America. 12—"Granite" layer. 13—Basalt layer. 14—Upper mantle. 15—Asthenosphere. 16—Sedimentary layer

Deep water and the severe natural environment highly complicate, and make more expensive, this deposit's development. According to estimates this region's gas reserves exceed the potential of Norway's Troll deposit by approximately twice, which will make it possible to supply gas to all of the north and northeast of the European part of the country and to export it abroad in the future.

South of the East Barents Sea basin lies the huge **Timano-Pechorskiy** oil and gas basin, covered in the north by waters of the Barents Sea. Gas and oil deposits have been revealed right on the coast, and a small oil deposit has already been exploited for several years on the island of Kolguyev, producing around 1 million tons of oil annually. The large **Prirazlomnoye** oil deposit was recently discovered near the shore. Its exploitation is fully realistic, and not all that technically difficult.

The **South Kara** oil and gas basin embraces the southern part of the Kara Sea and Arctic tundra of Yamal and Gydan peninsulas. The prospects of this basin are extremely great. This is the site of the Western Siberian oil and gas zone. The gas deposits of Yamal extend to the seacoast. In recent years, prospectors discovered two new gas giants not inferior to the reserves of the Shtokmanovskoye deposit in the Kara Sea—the **Leningradskoye** and **Rusanovskoye** deposits. These are "multistory" hydrocarbon deposits: There is gas in the upper "story," while below it there are as yet unrevealed deposits, most likely oil. If the predictions are confirmed, the Kara Sea will become a true Klondike. It must be said, however, that getting the oil out will be a most difficult task.

Little is known of the geology of seas east of the Taymyr Peninsula. The geophysical explorations that always precede drilling of exploratory holes have not even been started yet. But two potential oil and gas basins may be identified conditionally in this region: The **Laptev Sea** and **East Siberian**. The indirect signs that make it possible to place a high value on the prospects of their oil and gas content include the thick layers of sedimentary rock and presence of geological structures that may contain hydrocarbons. Small deposits of oil and the very large **Olenekskoye** bitumen deposit, where heavy oil seeps right up to the surface of the earth (the reserves are estimated at 15 billion tons), are present on the terrestrial periphery of the Laptev Sea basin. There are all grounds for believing that huge accumulations of oil and gas are concealed beneath the waters of these Arctic seas.

The Arctic shelf of North America, which belongs to the USA and Canada, is situated on the other side of the Arctic Ocean. Hundreds of holes have been drilled, and 60 marine and offshore deposits have been found. The total estimate of the potential resources of North America's Arctic shelf is 4 billion tons of oil and 4.5 trillion m^3 of gas. These reserves are distributed among three oil and gas basins.

The **North Alaskan** oil and gas basin, which has an area of almost 500,000 km^2, includes the northern slope of the Alaskan Peninsula and contiguous waters of the Chukchi Sea. Besides **Prudhoe Bay** (its reserves are estimated at over 1 billion tons of oil), the large **Kuparuk River** deposit (with reserves of 200,000 million tons) and a number of oil and gas deposits have been discovered here: **Milne Point, Seg Delta, Duck Island** and others.

The second oil and gas basin of this region—**the basin of the Mackenzie River delta and the Beaufort Sea**—occupies a relatively small area of 120,000 km^2. The first holes revealed two oil and gas deposits—Adgo and Garry. In 1978 the large **Kopanoar** deposit was discovered 50 km from shore. The extracted reserves are estimated at almost 250 million tons. Another oil giant—Koakoak—was discovered 30 km from this deposit. Other oil and gas (**Tarsyut, Nektoralik, Issungnak**) [transliterations] and gas (**Ukalerk**) [transliteration] deposits were established as well.

The **Sverdrup** oil and gas basin, which has an area of 280,000 km^2, occupies the larger part of the Canadian Arctic archipelago. Since 1969, 18 gas and oil deposits have been discovered in the basin. The largest—**Drake Point** and **Hecla**—possess gas reserves of 150 and 200 billion m^3 respectively. Exploratory drilling is being conducted here in a number of cases off of artificially frozen ice platforms—essentially directly off the ice of sea passages.

Concrete Castles or Underwater Cities?

Exploration and exploitation of marine deposits is a task that is perhaps not inferior in complexity to the problem of the exploitation of space. Its solution requires original engineering developments, sophisticated equipment and instrument support, and the personal courage of offshore oilmen. In order to drill oil and gas wells at sea, explorers use various platforms with dimensions sometimes attaining those of the Eiffel Tower or the Empire State Building. The cost of the platforms is up to $2 billion. These are truly castles of reinforced concrete, standing on the sea-bed and towering dozens of meters above the water's surface. For example the Statfjord platform is designed to drill 42 production wells and to extract up to 33,500 m^3 of oil daily (the capacity of the oil storage tanks, which are erected in subsea caissons, is over 300,000 m^3.

Such platforms have come to be called **gravity platforms**. They are built in deep building docks erected in natural deep-water fords, after which they are towed to and sunk at the drilling location. A gravity platform is installed on a supporting slab (the area of the Statfjord platform's slab is 18,000 m^2). A storage area for the extracted oil is built into its lower section, and the drilling machinery and housing space are located in the upper section. A vertical column connects the lower section to the upper deck, the distance between which is sometimes more than 150 m. A modern gravity platform can be installed in seas up to 600 m deep. The question that arises is this: Is it profitable to extract subsea oil in such an expensive way? Let's consider the experience of work in the North

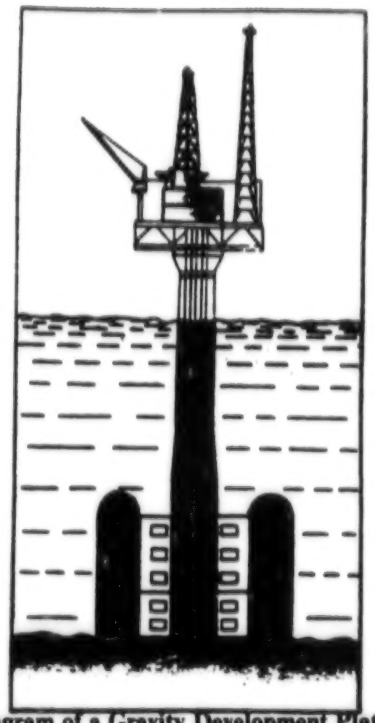


Diagram of a Gravity Development Platform

Sea. Almost $90 billion have been invested since the beginning of its development for oil (since 1962). This money was spent on fundamentally new technology, equipment, a fleet, and integrated maintenance bases. But all of this has made an average profit of $5-6 possible on every invested dollar.

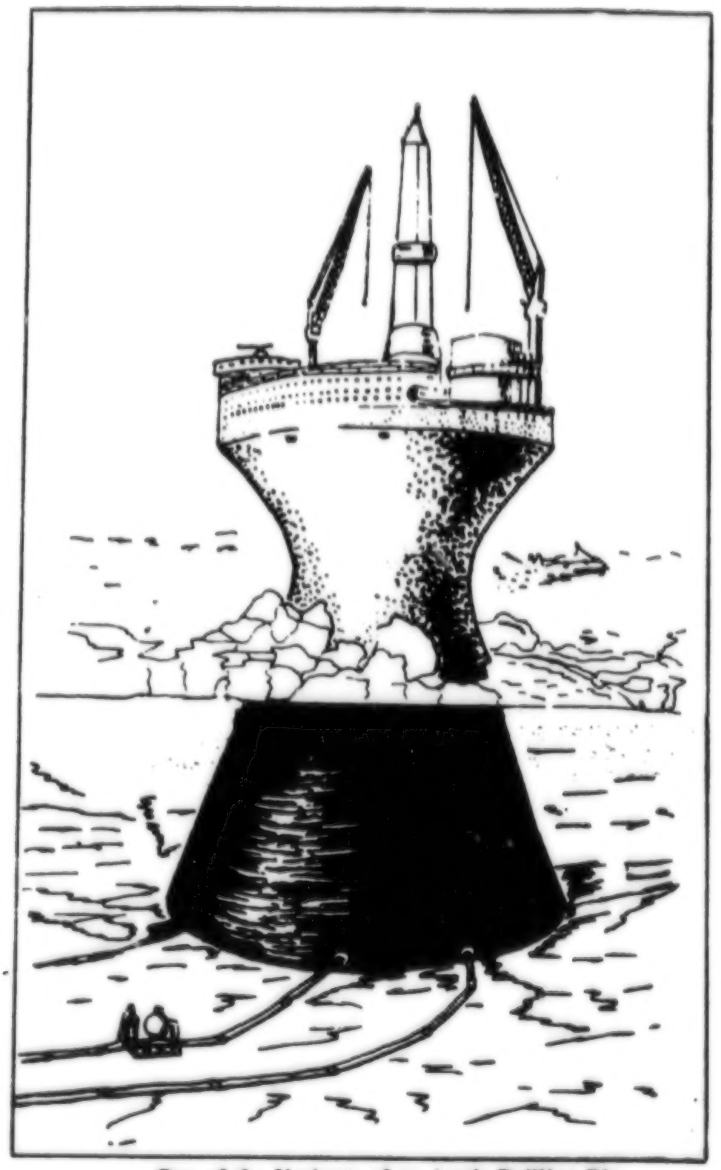
However, these reinforced concrete drilling castles can operate only in water basins that do not freeze over—the North Sea is free of ice year- round owing to the warm Gulf Stream. But in the Arctic, totally different technical concepts are required. In our country, a seasonal work schedule is followed in drilling exploratory holes in the Barents and Kara seas: Drilling is carried out in summer, when the water basin is not covered by ice. In winter, the drilling platform stands idle in a building dock—an expensive proposition, since every day of idleness costs an average of 20,000 rubles. Special drilling vessels of a reinforced ice class, built by Finland's Rauma-Repola [transliteration], are used in our country. They are intended to drill in water up to 600 m deep, and they are capable of penetrating up to 6 km of subsoil. In winter they move for work to other basins that do not freeze over. Three such vessels are now operating on the shelves of the USSR—the "Valentin Shashin," "Mikhail Mirchink" and "Viktor Muravlenko."

But drilling vessels are not suited to production operations; nor do gravity platforms meet the requirements of Arctic conditions. Special **iceproof platforms** are used for these purposes in freezing water basins. These are enormous heavy structures made from steel and concrete, capable of withstanding the onslaught of huge ice fields. Ice digs the Arctic seas like a plow in water up to 50 m deep, leaving deep furrows behind. Iceproof platforms often recall two cones, one set within the other. The upper cone breaks apart and fends off the advancing ice (the cost of such reinforced concrete platforms is $300-500 million). Other ice-breaking systems capable of grinding down thick ice are also being developed. Having icebreakers patrol around marine production platforms is also proposed. However, all of these contrivances have their limit; moreover, they make development of Arctic "black gold" extremely complicated.

Marine oilmen have recently accumulated a certain amount of experience in using subsea **well completion** systems, adapted to wells with their heads located on the sea-bed. The essence of the idea is this: Production wells drilled as a "cluster" from a single platform are connected by flexible pipelines through a special device to a common drain that takes oil up to the water surface to a floating terminal or a storage tanker. The oil is transferred and carried away by tankers from here as necessary. Pipeline transport can be used to transfer the product to shore. Specialists feel that this is the only method that can be used to develop marine deposits when the water is hundreds and thousands of meters deep. Around 500 such systems are now working on the world's shelves, with almost 30 percent of them located in the North Sea. Subsea systems are used in seas that do not freeze over. As far as the Arctic is concerned, things are still just in the planning stage.

High hopes are associated with subsea oil fields. Such an underwater city would most likely look like this: Several "clusters" of production wells are scattered over the entire body of the deposit in such a way that they would drain the deposit uniformly. For this purpose the well bores are made slanted and horizontal. Wells are drilled in the summer, and their heads are located in a special bunker (caisson) dug into the sea-bed and covered by a concrete dome. Flexible hoses move the product (oil or gas) to special oil field complexes, which are also installed on the sea-bed. These may be concrete hemispheres containing modular devices by which the product is purified and prepared for transport. The transportation problem can be solved in different ways: Either a pipeline may be laid to the shore, or tankers may be filled at sea above the deposit without mooring. Submarines may be used as an energy source, to provide additional equipment space, and for diver maintenance.

We would hardly see the advent of underwater oil fields on the bottom of the Barents or Kara Sea in the present century, but there can be no doubt that the future belongs to them. All of this will of course require totally new engineering concepts, and creation of automatically operating, highly complex mechanisms and systems that can support unmanned oil and gas extraction procedures. Reaching these objectives will require the efforts of several industrially developed countries. Today for example, the plan for a joint Soviet-Norwegian-American venture to develop the Shtokmanovskoye giant is actively being discussed. According to Norwegian specialists, depletion of oil and gas resources in the



One of the Variants of an Arctic Drilling Rig

USSR and growing difficulties in exploring the largest deposits may place our oil industry in a critical position. This is why we must expand work in the Barents Sea. This region must become a permanent object of activity of oil and gas industry. So that plans for undersea development of deposits in the Arctic seas, which seems only a dream today, could soon become a reality. But we need to prepare for this right now.

Future Generations Need a Clean Arctic

There is one other important aspect of developing the Arctic— **preserving its ecological cleanliness.** Unfortunately, sometimes oilmen inflict wounds that take a long time to heal on fragile Arctic nature. In spring 1989 news of the tragedy in Prince William Sound on the southern shore of Alaska flashed around the world. Around 35,000 tons of oil leaked into the sound from holes in the tanker "Exxon Valdez." Many hundreds of square kilometers of the water basin were covered by a black film. It contaminated thousands of kilometers of coastline, and it became the cause of death of numerous birds and marine animals. According to press reports, Exxon will have to spend not less than $2 billion on the clean-up operations.

Nor are such disasters rare in our waters. In May 1989 a marine platform caught fire in the Caspian. A little earlier, an enormous quantity of crude oil entered Caspian waters from a break in an oil pipeline, forming a

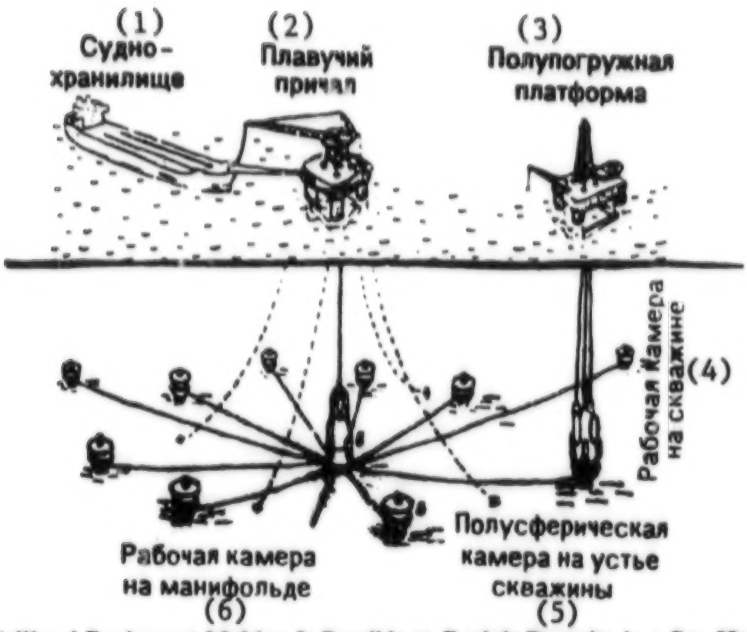


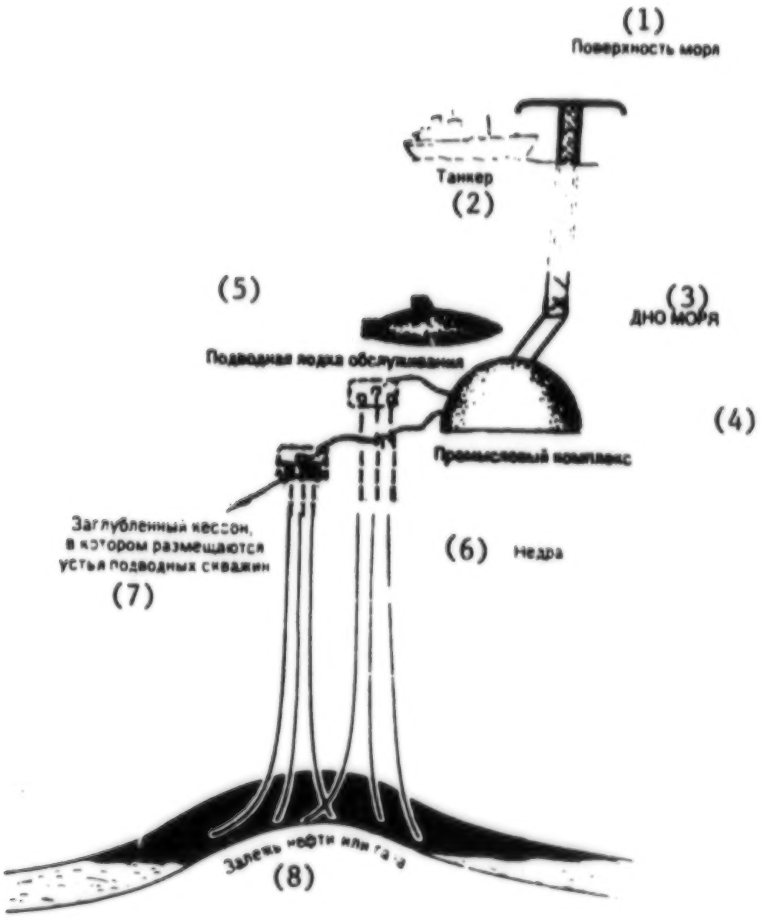
Diagram of Subsea Wellhead Equipment Making It Possible to Exploit Deposits in a Sea Hundreds of Meters Deep
Key: 1—Storage tanker. 2—Floating terminal. 3—Semisubmerged platform. 4—Working chamber at well. 5—Hemispherical chamber at wellhead. 6—Working chamber at manifold

huge spot. Systematic dumping of wash water containing a high concentration of oil into the Caspian basin is leading to its catastrophic contamination. Consider this in light of the fact that Arctic nature recovers much more slowly than do waters of the southern seas. And development of the Arctic's resources must proceed much more cautiously.

But how can we guarantee the ecological safety of Arctic water basins? First of all, work on the shelf requires specially trained specialists—from geologists to vessel captains, since accidents occur in most cases due to incompetency, mismanagement and a careless attitude toward the work. Second, the drilling rig must be outfitted with the necessary means of ecological protection—oil booms, pumps, back-up containers, and cleaning and firefighting resources. Third, special shutoff valves, preventers and other blowout control devices of higher quality and strength must be employed when drilling offshore wells and exploiting the deposits. Fourth, the places of work of the oilmen must be regularly monitored by nature conservation organizations using satellite warning systems. These services should be armed with effective weapons—special vessels and other equipment. Fifth, workers at sea must observe safety and environmental protection requirements most strictly.

One final thing. The process of developing marine deposits consists of several stages. The very first is that of prospecting and exploration with the objective of preparing the raw material base for subsequent exploitation of the deposits. This is the stage we are in right now, and it will continue for not less than another decade. Concurrently we are rehearsing the deposit development procedures in certain test areas, and we are designing and improving the equipment. This is the safest stage in ecological respects, and it requires relatively low outlays. But it must be carried out to its conclusion, since otherwise the rate of the entire process of developing oil and gas resources of the continental shelf will slow down drastically.

Development of "black gold" reserves in the subsoil of our northern seas is necessary to the development of Soviet oil and gas industry. It is hardly something that could be reasonably postponed. There has been a stable tendency since 1988 for annual oil extraction to fall in the Soviet Union; depletion of oil reserves is not the least important factor in this trend. If it persists, by the year 2000 we will be extracting around 450 million tons of oil per year, instead of the anticipated 630-640 million tons. At the same time, according to specialists the subsoil of the Arctic may produce up to 100 million tons of oil annually. This is an extremely tangible addition. But in order to acquire it, we must do many things today. We need to solve the problem in a technically competent way, without haste, but also without unjustifiable delays, with a guarantee of ecological safety of the Arctic—this severe and beautiful land.



Arctic Subsea Field of the Future

Key: 1—Sea surface. 2—Tanker. 3—Sea-bed. 4—Field complex. 5—Support submarine. 6—Subsoil. 7—Buried caisson housing subsea wellheads. 8—Oil or gas deposit

Soviet Scientists Examine Induced Earthquakes

917N0135A Moscow TRUD in Russian 19 Jun 91 p 3

[Article by T. Kasumova, TRUD correspondent: "When the Earth Trembles; the USSR Academy of Sciences Has Removed the Secrecy Stamp From a Subject of Interest to All"]

[Text] The war in the Persian Gulf and the earthquake in Georgia are mysteriously related. This and other aspects of "induced seismicity" became the subject of discussion at an international conference held in Baku under the aegis of the Earth Physics Institute, USSR Academy of Sciences, and the Geology Institute, Azerbaijan Academy of Sciences.

Strictly speaking, the idea of a possibility of a technogenic influence on an earthquake is not new. Already in 1945 it was expressed for the first time by the American scientist Carder, who postulated that a powerful tremor in the neighborhood of the artificial Lake Mead on the Colorado River was provoked by construction of the dam. At that time the hypothesis of this scientist was not taken seriously. But....

Twenty-two years later a strong earthquake in the neighborhood of the Koyna dam in India almost completely destroyed the small city situated nearby. About 200 people died. More than 1500 were injured and thousands were left homeless. The force of the tremor was so great that it was felt even in Bombay, 230 km from the epicenter. At the beginning of the 1960's there were three earthquakes in a row in the neighborhood of dams—at Hsinfeng-yang (China, 1962), Kariba (Zambia, 1963) and Kremasti (Greece, 1965). It was no longer possible to ignore the probability of an interrelationship between these phenomena.

The well-known Indian scientist Doctor Harsh Gupta, an adviser of Cochin University of Science and Technology, closely concerned with this problem from the first days of the earthquake at Koyna, is one of the leading specialists in this field.

He states: "The effect of man-made reservoirs on the tectonic process is today a generally recognized fact. Now we know of more than 70 cases of an increase in seismicity in regions of dams and dikes. Eleven of them had a magnitude greater than five, including the Aswan dam event. However, a high percentage of the large reservoirs in the world exert no such influence on the deep layers. Why? Unfortunately, there is much about this phenomenon which we still do not understand. Nevertheless, it also is possible to speak of definite regularities. In particular, it has been established that under special geological and hydrological conditions there is an increase in seismicity when the depth in water bodies is greater than 100 m. A dependence between an intensification of tectonic activity and a sharp drop in water level is clearly traced."

These conclusions, drawn on the basis of many years of observations and analyses by Doctor Gupta and his colleagues and by other scientists working within the framework of an international program implemented under the UNESCO aegis, are today known to a wide range of specialists. It is difficult to exaggerate the practical importance of this knowledge. However, the broader the volume of accumulated information becomes, the more evident it is how far we are from a full understanding of the processes transpiring in the Earth's deeper layers.

It would seem that knowing the influence of sharp water level variations one would think a very long time before damming off the Kara-Bogaz-Gol, because the Caspian, although being large, is nonetheless a lake and should be acted upon by the very same mechanisms as act on closed artificial water bodies. This idea was expressed for the first time by I. Kerimov, doctor of physical and mathematical sciences, deputy director of the Geology Institute, Azerbaijan Academy of Sciences. And now, unfortunately, there is factual confirmation: according to data cited by the Baku scientist F. Kadirov, rapid water level drops in the Caspian clearly coincide with an increase in earthquake frequency and force. In the light of this hypothesis it also is evidently necessary to reexamine the role played by Lake Sevan, in recent years experiencing a sharp water level drop, in the Spitak earthquake.

Kerimov also postulated that in all similar cases associated with the effects of induced seismicity a release of energy also arises rather far from a water body, in a territory greater by a factor of 5-10 than its own dimensions. Relative to the Caspian, this is all of the Caucasus and Central Asia, shaken during recently by earthquakes, and these events have been especially destructive because sharp water level drops are by no means the sole factor provoking more intensive radiation of the crust.

In the opinion of the leading Soviet scientist in this field, A. Nikolayev, corresponding member, USSR Academy of Sciences, the Semipalatinsk test range bears the responsibility for this. Specialists of the laboratory which he heads in Moscow at the Earth Physics Institute, the only one in the country investigating the subject of induced earthquakes, have accumulated many data confirming this hypothesis. However, it became possible to publish these findings only now, after removal of the stamp "C.S." ("Completely Secret") from this subject matter. And so, according to these data, the exciting character of underground nuclear shots on processes in the Caucasus and Central Asia region is quite evident. The force of release of intraterrestrial energy is the more destructive the greater the impact imparted by the provoking factors. Today these include not only shots and dams, but also the working of different mineral deposits, artificial change in stratum pressure and even war. The "superposing" of these factors on one another, stated the Czechoslovakian seismologist Doctor Dan Prokhazkov, citing his own observations in many coal-producing regions of the Earth, is dangerous primarily because it is capable of causing a powerful tremor even in stably aseismic regions.

In the opinion of A. Nikolayev and I. Kerimov, as a classical example of this it is possible to cite the earthquakes at Gazli, occurring "under the cross fire" of the shots at Semipalatinsk and intensive gas production. The hypothesis of a technogenic nature of the catastrophe was expressed by the scientists immediately after the first earthquake in 1976. At that time they warned that industrial work in this zone must be carried out only under rigorous control. Otherwise there could be a repeated, far more rapid "maturing" of the focus. And so it happened. A repeated powerful earthquake at Gazli occurred eight years later. Meanwhile, according to estimates made by geologists and geophysicists, under natural conditions its preparation would require not less than 10,000 years.

A similar situation also is developing with the Caspian, which as a result of uncontrollable industrial activity and other technogenic factors is being transformed, to use the graphic expression of the Baku scientist A. Manafov, into a "mounted machine gun," with salvos of earthquakes "spraying" all the regions along its perimeter. The possible explanation of the nature of the recent earthquake in Georgia, expressed by I. Kerimov in confirmation of this hypothesis, became a true sensation. in his opinion the tremor provoking and accelerating the movement of the Caucasus Mountains, could be... the war in the Persian Gulf. This opinion was based on data from the most modern instruments. And these data are as follows: immediately after the onset of the war the instruments at the Geology Institute registered an increase in the noise level, whose character gave evidence of excitation of the deeper layers by an artificial source.

"In fact, when monitoring noise some unusual signals appeared almost a day before the events," stated Ikram Gadzhiyevich, "and later we related them to major movements of equipment on the eve of military operations in the Persian Gulf zone. With the onset of bombardment, moreover, the intensity of the signals increased sharply. The pattern of the noise field acquired a clearly expressed character not leaving doubts as to its artificial origin. And this excited state of the medium persisted for a long time after the end of military operations."

Meanwhile, judging from the calculations of the Baku scientists, the violence from the storm may not be confined to Georgia alone. The consequences of the mass bombardments of Iraq, including tectonic aftereffects, will for a long time shake the planet. The recent occurrences of weak earthquakes in adjacent regions serve as a confirmation of this. The probability of more significant tremors in Iraq, Turkey, in western Iran and other regions is not precluded. And this, in turn, may result in a further increase in seismicity, because, according to recent data, not only the external medium, but also earthquakes themselves are capable of initiating new tectonic processes. Moreover, activation of the Earth's surface over large areas also may cause strong weather anomalies. It was noted at the conference that such effects in nature observed during the last few months require the very close attention of scientists.

These data and hypotheses, giving rise to sharp interest among the conferees, naturally require supplementation and refinement. As a beginning it was decided to make inquiries and carry out an independent analysis of data from seismic stations located closer to the site of the events.

"This is necessary not only to determine the scales of the ecological catastrophe caused by the war in the Persian Gulf," stated A. Nikolayev at the end of the conference. "What is important is that it possibly may enable us to advance a little in our understanding of the mechanism, the nature of the technogenic effect on the processes transpiring in the Earth's interior. Although induced seismicity constitutes a negligible part of the earthquakes which occur, the need for understanding the consequences of man's activity is becoming increasingly acute."

Lithospheric-Ionospheric Relationships Before Earthquakes

917N0140A Moscow IZVESTIYA AKADEMII NAUK SSSR: FIZIKA ZEMLI in Russian No 3, Mar 91 pp 26-35

[Article by V. A. Liperovskiy, V. A. Gladyshev and S. L. Shalimov, Earth Physics Institute imeni O. Yu. Shmidt, USSR Academy of Sciences]

UDC 550.388.2

[Abstract] The most reliable modern experimental results obtained in research over the seismically active regions of the Caucasus, Central Asia and Kamchatka are analyzed and systematized. The characteristic temporal and spatial scales of the extremal manifestation of specific ionospheric disturbances preceding earthquakes are discussed. The conclusion is drawn that the neutral component of the ionosphere possibly plays the key role in generating these disturbances. The results of vertical sounding in seismically active regions indicate that: the nighttime lower ionosphere (E_S layer) is characterized by increased visibility during the two days remaining before an earthquake; during this same period there is a large-scale increase in density in the ionospheric F-layer, against whose background it is possible to discriminate a vortical relative decrease in density; an increased number of quasiwave density variations at 300 km with a duration two-three hours correlates with these phenomena. The results of observations of night airglow of seismically active regions indicate that: glow in the line 5577 A several days prior to an earthquake is characterized by increased variability; at the same time there is usually a stable increase in 5577 A intensity which attains a maximum several days prior to an earthquake; several days prior to an earthquake there is an increased intensity of 6300 A emission which a day before an event is replaced by a decrease and attains a minimum several

hours before an earthquake. An increase in the variability of 5577 A and f_0E_s in the ionosphere of seismically active regions may have a common basis evidently associated with a definite variability in the neutral component. Accordingly, explanation of the increase in concentration at the F-layer maximum at considerable distances from an epicenter requires examination of large-scale movements of the neutral component associated with changes in meteorological fields. References 31: 26 Russian, 5 Western.

Use of Space Images in Study of Developmental Features of Recent Tectonic Structures in Territory of Turan Plate

917N0130A Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 1, Jan-Feb 91 pp 98-102

[Article by M. I. Burleshin, Lithosphere Institute, USSR Academy of Sciences, Moscow]

UDC 551.24:629.78

[Abstract] Space images have now been used extensively in studying the geological structure of the Turan plate, yielding much new data on local tectonic structures, primarily on those of recent formation. Emphasis was on use of space images with a local level of generalization showing the surface in a broad zone of the visible spectrum during summer and spring. In this region three principal phases of recent tectonic activity were discriminated: Oligocene, Pliocene and Quaternary. Each of these phases was distinctively expressed in the geological structure of the platform mantle. Interpretation of these images made it possible to detect changes in relief, mineralogical composition of recent deposits, rock fissuring and evidence of activation of exogenous processes and to relate them to the three phases of recent tectonic activation. Five types of development of local structures were defined. Each of the phases and their characteristic local structures are described in detail. The research revealed the great possibilities of use of space images in studying such difficult geological problems as study of the history of tectonic development of geological structures in the recent tectonic stage. The wealth of space image information can be used in solving specific economic problems. On the Turan plate the interpretation of such images made it possible to search for fresh water, evaluate changes in the geological medium as a result of technogenic impact, prepare geological engineering studies for construction of large hydraulic structures, detect sectors where surface runoff could be stored and where oil and gas deposits might be found. Figure 1; references: 4 Russian.

Optimal Frequency Range of Correcting Filtering for Seismic Records

917N0121A Kiev GEOFIZICHESKIY ZHURNAL in Russian Vol 13 No 1, Jan 91 pp 62-69

[Article by Yu. K. Tyapkin, Kiev Geological Section, Ukrainian Geological Prospecting Scientific Research Institute]

UDC 550.834

[Abstract] In the deconvolution problem, when there is a relatively large error in evaluating elementary signal shape, the optimum Wiener filter may lose its advantage in comparison with Backus filtering in a limited informative range on a seismic record in which correcting filtering is employed. Errors in solution of the inverse problem by convolution-type equations by the two methods are compared quantitatively. The proposed algorithm assumes the presence of at least one interval on the frequency axis within which the signal predominates over noise. The algorithm was tested along a profile in the Dnepr-Donets depression. Formulas proposed earlier were used in evaluating the power spectra of the signal component and noise. The POLF program used in computing common depth point seismograms was employed. The automatically determined optimal frequency range 8-47 Hz, identical for band and correcting filtering, reflects the fact that the power spectra of the signal component and noise intersect only at the two points 8 and 47 Hz. The proposed method for choosing the optimal frequency range of band and correcting filtering is a theoretical validation of a heuristic algorithm widely used in practical work based on intuitive concepts. Figures 2; references 7: 6 Russian, 1 Western.

Influence of Local Upwellings on Spectra of Sea Water Light Extinction Index in Gulf Stream Region

917N0143A Moscow OKEANOLOGIYA in Russian Vol 31 No 2, Mar-Apr 91 pp 228-232

[Article by G. S. Karabashev, Atlantic Division, Oceanology Institute imeni P. P. Shirshov, USSR Academy of Sciences, Kaliningrad]

UDC 551.463.5

[Abstract] Spectra of the light extinction index in water samples collected in the Gulf Stream region were measured simultaneously with hydrological and hydrochemical observations in August-September 1984 and 1985. Local water upwellings frequently occur there due to meandering of the current and eddy formation. The measurements were made using a spectral transparency meter with a 1-m base in the wavelength range 310-590 nm. Water samples were taken from the surface with a polyethylene pail and from deeper layers with vinyl plastic bathometers. Observations were made for three weeks at stations along nine runs with stations 30 miles apart. The collected data made it possible to determine year-to-year variability of light extinction indices at the ocean surface and compare these data with the corresponding indices at the depth of the upper boundary of the seasonal thermocline (50 m) and in the main thermocline (400 m). Changes in the index were compared with changes in water temperature, salinity, density and content of dissolved oxygen and silicon. It was found that by using the depth of the isotherms it was possible to identify local upwellings and it could be shown that the absolute light extinction index values, the form of the light extinction spectra and their relationship to oceanological characteristics may be considerably dependent on the intensity and "age" of local water upwellings. It is suggested that this dependence can serve as a basis for rapid methods for contact or remote detection of such upwellings in the open ocean. Figure 1; references: 5 Russian.

Temporal Variability of Sea Water Cavitation Strength

917N0154A Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 317 No 2, Mar 91 pp 458-461

[Article by V. I. Ilichev, academician, V. L. Korets and N. P. Melnikov, Pacific Ocean Oceanological Institute, Far Eastern Department, USSR Academy of Sciences, Vladivostok]

UDC 532.528

[Abstract] Only a few experimental studies have been made of the cavitation strength of real sea water, but these have revealed considerable temporal variations of cavitation strength. Special research was therefore carried out for determining the nature of these variations in two regions which differ considerably in their hydrological conditions. The first region was a closed shallow-water sea embayment and the second was in the open part of the Atlantic Ocean. In both cases the measurements were made in the near-surface layer at equal time intervals (0.5 hour) and the data were analyzed by autoregression methods. In addition to the strongest diurnal component there are significant spectral components with shorter periods: 14.3, 7.6, 6, 2.6, 1.9, 1.5 and 1.08 hours. An attempt was made to ascertain the factors responsible for each of the observed periods. This research revealed that the temporal variability of sea water cavitation strength in different regions has an extremely complex character and is evidently related to the presence of the general diurnal rhythm of physical, chemical and biological processes in the ocean, especially tidal phenomena and the diurnal migration of plankton, as well as oscillations of the jump layer under the influence of internal waves. Figures 4; references: 5 Russian.

Evolution of Angular Distribution of Light Scattered on Absorbing Anisotropic Medium

917N0146A Moscow IZVESTIYA AKADEMII NAUK SSSR: FIZIKA ATMOSFERY I OKEANA in Russian Vol 27 No 3, Mar 91 pp 297-303

[Article by A. V. Aistov, V. G. Gavrilenko and S. S. Petrov, Gorkiy State University]

UDC 551.521.3

[Abstract] A numerical study was made of the angular diagram of light brightness in the depths of the sea when there is slant illumination of the calm surface by a stationary infinitely broad beam. A qualitative comparison of the results obtained by the Monte-Carlo method in a three-dimensional problem is made with a numerical solution of the transfer equation in a two-dimensional medium. It is shown that the form of the angular diagram may differ considerably from a Gaussian form and that the width of the angular distribution of light at some depth may have a maximum exceeding the asymptotic value. The following regularities were observed. In "pure" ocean waters with a survival probability less than 0.5 with large surface illumination angles a light regime not earlier described in the literature is evidently possible. In its initial stage, when rotation of the center of gravity of the angular diagram of light toward the vertical is still insignificant, there is an angular diffusion of radiation which is all the more rapid the stronger the absorption is in the water. In particular, the angular distribution should be blurred more rapidly for those wavelengths which attenuate more strongly in the sea. In such a case it is characteristic that in the plane of incidence it is blurred more rapidly than in the section perpendicular to it. In this stage there may be deformations of the angular diagram which are the more substantial the lesser the probability of survival of a photon in the medium. With further penetration into the depths of

the medium, when the center of gravity of the angular spectrum is displaced considerably toward the vertical, the nature of evolution of its width is reversed: the angular diagram begins to be narrowed, tending to its asymptotic form in a deep regime. Figures 4; references: 14 Russian.

Multiday Observations of Wind Wave Packet Evolution

917N0146C Moscow IZVESTIYA AKADEMII NAUK SSSR: FIZIKA ATMOSFERY I OKEANA in Russian Vol 27 No 3, Mar 91 pp 326-334

[Article by Yu. N. Goryachkin, S. A. Grodskiy, V. A. Ivanov, V. N. Kudryavtsev, A. D. Lisichenok and Ye. N. Pelinovskiy, Applied Physics Institute, USSR Academy of Sciences; Marine Hydrophysics Institute, Ukrainian Academy of Sciences]

UDC 551.466.8

[Abstract] A four-day cycle of observations was made of a fragment of a wave field which included a group of short-period internal waves (IW). Observations were made in the northwestern part of the Tropical Atlantic in a region characterized by horizontal homogeneity of hydrological structure. The measurements were made on the 39th cruise of the Akademik Vernadskiy in May 1989. During the first 60 hours of the experiment the energy of the IW packet increased, after which the decay of a group of short-period IW occurred, which was accompanied by an energy decrease and the appearance of waves with an asymmetric profile. Observation of the evolution of an IW packet from the stage of its generation to its decay revealed the following. A group of IW was always situated in the depression of a low-frequency displacement of the thermocline. The group velocity of a packet corresponds to the theoretical velocity with allowance for the Doppler shift of an IW associated with a low-frequency subsidence current. The period of oscillations in a wave group increases monotonically, which may be related to a nonadiabatic evolution process. The packet energy increases in the initial stage of evolution. A possible explanation for this is the self-excitation of an IW during interaction with oncoming wind waves. With an increase in the energy of an IW group the following phenomena were observed: radiation of a second IW packet, which due to a lesser group velocity began to lag; a "sharp" energy decrease with the formation of thermocline oscillations resembling a "chain" of solitary waves. The generation of IW and their decay occurred under conditions of horizontal homogeneity of the ocean. With the incidence of the observed wave field on a front the appearance of high-frequency thermocline oscillations was observed and the identification of the characteristic features of the investigated fragment became impossible. Figures 5; references 7: 5 Russian, 2 Western.

Changes in North Atlantic Thermal Regime

917N0125B Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 2, Feb 91 pp 66-70

[Article by D. I. Antonov, P. Ya. Groysman and S. B. Nikolskaya, State Hydrological Institute]

UDC 551.463.6.001.572(261.1)

[Abstract] During recent years systematic changes in water temperature below the active layer have been discovered in the North Atlantic. A study was made to clarify the possibility of penetration of the water temperature variations observed at the surface during the last century into the deep layers and to compare the changes induced by this penetration and the changes in the thermal regime observed there. A simple zonal model of the propagation of heat into the depths of the ocean is outlined which demonstrates an intercausality of the observed modern changes in water temperature at the surface of the North Atlantic and below the seasonal thermocline. The signs, order of magnitude and all the principal statistically reliable features of the observed pattern of modern changes in the thermal regime of the deep ocean are satisfactorily reproduced by the proposed model. These features include a temperature decrease in the upper 300-m layer of the ocean; a subsidence of regions of negative temperature trends to depths 500 m (30-35°N) or 1500 m (50-65°) in latitude zones in which descending water movements predominate; an extensive region of positive water temperature trends in the middle part of the North Atlantic (25- 45°N) at depths 1000-2000 m. Figures 2; references 11: 4 Russian, 7 Western.

Diagnosis of Hydrogen Sulfide Pollution of Black Sea Based on Gas Exchange With Atmosphere

917N0125C Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 2, Feb 91 pp 80-83

[Article by L. V. Yeremeyeva, A. Kh. Degterev and S. Kh. Degterev, Marine Hydrophysics Institute]

UDC 551.464.34:551.465.7(262.5)

[Abstract] The saturation of the layer 0-10 m in the Black Sea with oxygen and carbon dioxide was computed using information in the databank of the All-Union Scientific Research Institute for Hydrometeorological Information-World Data Center. Saturation data were averaged in 1° grid squares. In general, the surface waters are undersaturated with oxygen by 4 percent and supersaturated with carbon dioxide by 15 percent. The flows of these gases through the sea surface are calculated. The relative receipts of hydrogen sulfide from geological formations and from ancient bacterial sources are estimated. A map shows the averaged seasonal distributions of the relative saturations of surface waters with oxygen

and carbon dioxide. The range of variability of saturation of water with oxygen after averaging is +/-20 percent. The spatial structure of the oxygen field is simplest in summer and winter when over the greater part of the sea the saturation of the surface layer with oxygen is close to equilibrium and the deviations usually do not exceed 5 percent. Despite a strong seasonal variability, during all four seasons the sea is undersaturated with oxygen, especially on the eastern shelf where the oxygen deficit attains 20 percent. The distribution of water saturation with CO_2 is considerably different. The Black Sea is greatly jsupersaturated with CO_2. The concentration of dissolved inorganic carbon in Black Sea waters is greater by a factor of 1.5 than in the ocean. In summer the entire region to the east of 38° is supersaturated by CO_2 by more than 30 percent. The supersaturation maximum is in autumn when in the western part of the sea it locally attains 40 percent. Figure 1; references 9: 5 Russian, 4 Western.

Low-Frequency Fluctuations of Signal Angle of Arrival in Randomly Inhomogeneous Ocean

917N0144A Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 316 No 5, Feb 91 pp 1226-1229

[Article by V. A. Gordiyenko, B. I. Goncharenko, A. A. Koropchenko, V. I. Ilichev, academician, L. A. Lutsik, A. B. Poleshchuk, A. A. Rudnitskiy and A. B. Sorokin, Moscow State University imeni M. V. Lomonosov; Pacific Ocean Oceanological Institute, Far Eastern Department, USSR Academy of Sciences, Vladivostok]

UDC 534.44:551.463.21

[Abstract] During sound propagation in a stratified ocean there are phase fluctuations resulting in considerable fluctuations in the amplitude of the registered signal due to the multiray character of propagation and frontal curvature. These fluctuations are manifested in an apparent change in the direction of signal arrival. However, experimental determination of the magnitude of this change is a difficult task at low frequencies. Computations have shown that the observed characteristic dimensions of small-scale inhomogeneities in the ocean, such as those caused by internal waves or rings, result in fluctuations of the angle in the horizontal plane not exceeding 0.1- 1°. An attempt was made to obtain experimental data on such fluctuations. A combined receiving system, consisting of an acoustic pressure detector and a vectorial detector registering the three mutually orthogonal components of oscillatory velocity, separated by a distance substantially less than the length of the acoustic wave, was used for obtaining experimental data on such fluctuations. Measurements made in different regions of the ocean confirmed the smallness of these angles. More significant fluctuations were observed in individual cases of a rigid thermocline and near frontal zones. Their characteristic spectrum is essentially dependent on the hydrophysical parameters of the propagation path. Such combined receiving systems will make possible reliable registry of small fluctuations of the angles of arrival of low-frequency signals and their spectral composition on the basis of the results of acoustic field measurements at a point and probably will be used in oceanic acoustic tomography. Figures 4; references: 3 Russian.

Some Results of Measurement of Spatial-Temporal Parameters of Internal Waves in High-Latitude Ice-Covered Basin

917N0127A Moscow OKEANOLOGIYA in Russian Vol 31 No 1, Jan-Feb 91 pp 62-67

[Article by S. V. Pisarev, Acoustics Institute imeni N. N. Andreyev, Moscow

UDC 551.466

[Abstract] The results of internal wave (IW) measurements on the shelf of a high-latitude ice-covered basin are presented. Such a situation warrants study because free IW with the periods of most of the principal tidal components may not exist there and the ice cover may change the mechanisms of generation and dissipation of the IW associated with the upper layer of the ocean. The IW were registered in the spring of 1988 in a region with an inertial period 12, 14 hours. The rate of drift of the measuring instruments varied from 3 to 13 cm/s, averaging 8 cm/s. During drift the depth decreased from 580 to 450 m. In a region measuring 120 x 120 km the ice continuity was 7-8 scale units. Waves were registered using an array of three distributed temperature sensors positioned on a single floe at the vertices of a right triangle. The levels of the registered spectra were below the model Garrett-Munk spectrum and increase with a decrease in depth. The semidiurnal oscillations of the thermocline and the energy of the short-period internal waves are described. The energy is periodically increased due to the receipt of essentially anisotropic groups of waves of the first-second mode with periods 0.6-one hour. The formation of the latter is attributable to the interaction between semidiurnal waves and bottom relief irregularities. Figures 3; references 18: 9 Russian, 9 Western.

Mesoscale Spatial-Temporal CO_2 Variations in Subarctic Front Zone in Pacific Ocean

917N0127B Moscow OKEANOLOGIYA in Russian Vol 31 No 1, Jan-Feb 91 pp 84-91

[Article by I. P. Semiletov and I. I. Pipko, Pacific Ocean Oceanological Institute, Far Eastern Department, USSR Academy of Sciences, Vladivostok]

UDC 551.464

[Abstract] A review of concepts on CO_2 exchange in the ocean-atmosphere system indicates that no definite conclusions can be drawn even at a qualitative level. Contradictory findings are attributable to the use of different models of CO_2 global migration between the ocean and atmosphere caused by differences in the scales of spatial-temporal averaging, nonuniformity of initial data and uncertainty with respect to the CO_2 exchange rate. In this article, in the example of a mesoscale areal survey of the parameters of the carbonate system carried out in the subarctic front zone of the Pacific Ocean, it is shown that the dynamics of CO_2 exchange in the ocean-atmosphere has a complex mosaiced structure which in a time interval not much more than one month may be radically restructured. In order to clarify this problem in part, two surveys were made on the 12th cruise of the Akademik A. Nesmeyanov research ship. The samples were taken from the surface each 15 miles and from other horizons (10, 25, 50, 100, 150 m) each 45 miles. The work was done along eight meridional runs, in the first test range each 1° in longitude and in the second each 30' in longitude. Seven hundred measurements of ΣCO_2 and pH were made. An analysis of the data revealed that the subarctic front zone is a spotty region of CO_2 invasion-evasion. This spottiness in all probability is related to the complexity of the hydrological situation in the research region. The resultant transport of CO_2 between the ocean and the atmosphere in different months is determined by a variable intensity of photosynthesis. Figures 2; references 29: 10 Russian, 19 Western.

Interaction Between Power Fluxes of Underwater Ambient Noise and Local Source

917N0124A Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 37 No 1, Jan-Feb 91 pp 99-103

[Article by V. I. Ilichev, V. P. Kuleshov, M. V. Kuyanova and V. A. Shchurov, Pacific Ocean Oceanological Institute, Far Eastern Department, USSR Academy of Sciences]

UDC 534.231+551.468.288

[Abstract] An in situ experiment was carried out in the deep open ocean to determine the possibility of existence of a compensation of two counter fluxes of acoustic power in an oceanic waveguide or in the air. It was found that there is a phenomenon of compensation of counter fluxes of acoustic power of ambient noise and a local source which results in the destruction of coherence between the vertical and horizontal components of oscillatory velocity and pressure. The phenomenon of the compensation of the power flux of ambient noise by the power flux of a local source also is observed in a shallow sea and in the coastal zone. It should also be observed in aeroacoustics. The discovered phenomenon explains the ragged character of many reciprocal spectra and coherence spectra of underwater ambient noise. A review of earlier studies by the authors reveals that in the entire frequency range used on all the reciprocal spectra and coherence spectra there are traces of competition of counter power fluxes. This phenomenon is also observed in the frequency range below 200 Hz where the noise of distant shipping predominates. The phenomenon of interaction of power fluxes in an oceanic waveguide affords a new methodological approach to research on the properties of acoustic fields. Figures 4; references: 6 Russian.

Use of Radar Measurements in Research on Hail Formation Processes in Clouds

917N0146B Moscow IZVESTIYA AKADEMII NAUK SSSR: FIZIKA ATMOSFERY I OKEANA in Russian Vol 27 No 3, Mar 91 pp 304-316

[Article by G. M. Ayvazyan, Radio Physics and Electronics Institute, Armenian Academy of Sciences]

UDC 551.574

[Abstract] A study revealed that the processes of propagation of millimeter and submillimeter waves in convective clouds have special characteristics making it possible to register three stages in the onset of hail formation in a cloud: increase in the size of superlarge (radius 85-1500 μm or more) drops, transition of these drops into a supercooled state, and finally, direct transition of these drops into ice-ice graupel or the covering of supercooled superlarge drops with an ice crust. As an indicator of the appearance of ice in a cloud for the first time it is proposed that use be made of the "window" of ice transparency in the submillimeter range. It is shown that with the transition of supercooled superlarge droplets into ice the radar reflection coefficient increases by a factor of more than two orders of magnitude in the ice transparency "window." An anomalous increase in the radar reflection coefficient in the transparency "window" of ice during the water-ice transition is a diffraction phenomenon and can be observed only with coexistence of three factors: the cloud must contain discrete, almost spherical ice particles; the size of the particles must be close to the wavelength of the ice transparency "window"; the wavelength of the sounding radiation must be close to the wavelength of the ice transparency "window." Only in such cases is it possible to use the ice transparency window 0.3-0.8 mm as an indicator of presence of hailstone nuclei in a convective cloud on the basis of the anomalous reflection of submillimeter waves. The transpiring of the described process is difficult due to the considerable absorption of submillimeter waves by water vapor in the surface layer and the unavailability of powerful radars. The problem can be solved by placing a generator and receiver aboard an aircraft or satellite. Figures 5; references 39: 19 Russian, 20 Western.

Automated Determination of Space Coordinates of Points From Single Aerial Photograph

917N0151A Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 2, Feb 91 pp 36-39

[Article by V. A. Dargel, V. I. Ivanov and V. V. Mitrofanov]

UDC 528.721.1:681.3

[Abstract] Usually the spatial position of a point on an aerial photograph is determined photogrammetrically by processing a stereopair, but sometimes this must be done using a single photograph. However, traditional methods for processing individual aerial photographs are tedious, make possible only determination of the horizontal position of points and result in significant errors in visual transfer of points and features to a topographic map. In order to remedy this problem, with significant reduction in work input and increase in accuracy, it is proposed that this process be automated using analytical dependencies establishing a correlation between terrain points and the aerial photograph. This involves use of a mathematical model of terrain relief (MMTR). A canonical matrix structure of the MMTR is used. The theory and practical application of the method are discussed. The accuracy of automated solution of the problem was evaluated: with the materials used the rms errors were 10-15 m horizontally and 1-3 m vertically with computer calculations completed within 20-40 s after data input. The advantages of the proposed method over those previously employed are a higher accuracy and productivity attained by the use of a computer and the mathematical simulation of local relief and rigorous methods for processing elementary measurements. Its use affords a real possibility for automating the process of determining the coordinates and elevations of features from single aerial photographs taken with both topographic and nontopographic aerial survey cameras. The method can be used in finding the location of individual points and features, in compilation and revision of topographic, thematic and digital maps. Figures 2; references: 3 Russian.

Variability of Sea Surface Illuminance

917N0125A Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 2, Feb 91 pp 46-53

[Article by Zh. K. Zolotova, A. M. Kokorin and K. S. Shifrin, Oceanology Institute]

UDC 551.521:551.521.3

[Abstract] There have been virtually no direct observations of sea surface illuminance. An effort was therefore made to study this phenomenon using an indirect approach. The basic source used was previously published observational data on 30,000 total radiation measurements over the sea made under the most diverse conditions in different parts of the world ocean. A simple scheme is proposed for computing the integral and spectral illuminance of the sea surface through solar altitude and cloud coverage. The scheme is based on the close correlation between illuminance and irradiance through the light equivalent of radiation. Data on illuminance of the cloudless sky were obtained using a standard radiation model of the cloudless atmosphere. These data are quite consistent with data from direct observations at sea. It is recommended that data on mean cloud cover and its variance, which were registered earlier in observations from artificial earth satellites, be used in determining sea illuminance when there is an

arbitrary cloud cover. One table gives statistical estimates of cloud cover over different parts of the ocean for the periods 1967-1970 and 1975-1976; another gives the spectral density of natural irradiance for the cloudless atmosphere for solar altitudes 10, 30, 50, 70 and 90° for a series of wavelengths. Figures 2; references 11: 10 Russian, 1 Western.

Recurrence of Cloud Optical Depth Values Over World Ocean

917N0125D Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 2, Feb 91 pp 107-110

[Article by O. A. Volkovitskiy and L. N. Pavlova, Tayfun Scientific Production Association]

UDC 551.576

[Abstract] Data on cloud cover distribution are inadequate for evaluating the reliability of operation of various optical instruments. Very few data are available on the optical depths in clouds of different genera over the world ocean and these data shed no light on seasonal or latitude variations. Information is needed on the frequency of recurrence of optical depths of clouds at different wavelengths. In this article, on the basis of data available in the literature on cloud cover, an estimate is made of the frequency of recurrence of the optical depth of cloud cover over the world ocean with allowance for the recurrence of different cloud cover types. The frequency of recurrence of different cloudy situations over the ocean was taken from the Atlas of Simultaneous Occurrence of Different Cloud Types Over the Ocean (Boulder, Colorado, 1982) based on data from weather ships for the period 1965-1976. A table was prepared giving the probability of different cloud situations over the ocean in different zones from 80°N to 60°S. It is shown, for example, that as an average for the year one of the cloud forms prevails over the ocean in 37-44 percent of the cases, whereas in other cases there is a combination of two-three types of cloud cover. To the north of 45°N and to the south of 45°S stratiform clouds St, Sc (some or in combination with others) predominate over cumulus clouds (Cu, Cb). The reverse picture is observed in the ocean area from 15°N to 15°S. A formula is proposed for determining the probability of optical depth values for each latitude zone. Figures 2; references 9: 8 Russian, 1 Western.

Influence of Diffraction Conditions at Emitting Aperture on Time of Laser Pulse Propagation Through Refractive Atmosphere

917N0141A Tomsk OPTIKA ATMOSFERY in Russian Vol 4 No 1, Jan 91 pp 40-43

[Article by V. P. Aksenov, V. A. Banakh and B. N. Chen, Atmospheric Optics Institute, Siberian Department, USSR Academy of Sciences, Tomsk]

UDC 551.593:535.4:535.3

[Abstract] A further increase in the accuracy of laser range finding systems, necessary for solving problems in geodesy, geophysics and geodynamics, can be achieved only by using new laser sources with correction for atmospheric noise. One of the components of the errors in determining distances to a target is the atmospheric refraction arising due to nonuniformity of the refractive index of air. However, existing methods for correcting the refraction error are based on the formulas of geometrical optics and do not make it possible to evaluate the influence of nonuniformity of the refractive index on the propagation of pulsed laser radiation for arbitrary diffraction conditions in the plane of the emitting aperture and this may exert a substantial influence on the accuracy in determining distance to the target. This communication gives an analysis of the influence of the spatial distribution of the field in the plane of the emitting aperture of an optical source on the time lag of a pulse during its propagation in a refractive medium using a parabolic equation for the complex amplitude of the wave. It is shown that the arrival time of a light pulse in a refractive medium is dependent on the light diffraction regime at the exit aperture. Estimates of the errors in determining distances to targets, to which the existence of this dependence may lead, are given. Figure 1; references 7: 4 Russian, 3 Western.

Collisional Shift of CO_2 Lines and Its Influence on Propagation of Radiation of CO_2 Laser Through Atmosphere

917N0141B Tomsk OPTIKA ATMOSFERY in Russian Vol 4 No 1, Jan 91 pp 60-66

[Article by N. F. Borisova, Ye. S. Bukova, V. M. Osipov and V. V. Tsukanov, State Optical Institute, Leningrad]

UDC 535.34-15+539.196.3

[Abstract] The results of measurements of the collisional shift of individual CO_2 lines in air and in pure gas are presented for the bands 1.4, 2.7, 4.3, 4.8 and 9.6 μm. The determined values of the shift components fall in the range 0...plus or minus 0.25 $cm^{-1} \times atm^{-1}$. The influence of the collisional shift on the propagation of radiation of a CO_2-laser through the atmosphere is evaluated. It is shown that for individual generation frequencies the monochromatic transmission on a vertical path (with allowance for the shift and the laser generation frequency) may almost double. The results indicate that the detected effect of collisional shift of CO_2 lines may exert a substantial influence on the characteristics of molecular absorption of radiation of a CO_2-laser by the atmosphere. This effect also makes it possible to optimize the characteristics of laser systems based on CO_2-lasers, by a change in composition and pressure of the working medium displacing the frequency of laser generation into the microwindows of atmospheric transparency. Solution of such problems requires further experimental and theoretical research on the dependence of collisional line

shifts on the type of buffer gas and the thermodynamic parameters of the gas medium. Figure 3; references 20: 11 Russian, 9 Western.

Informational Content of a Priori Evaluations in Solving Inverse Light Scattering Problem

917N0141C Tomsk OPTIKA ATMOSFERY in Russian Vol 4 No 1, Jan 91 pp 88-95

[Article by S. L. Oshchepkov and O. V. Dubovik, Physics Institute, Belorussian Academy of Sciences, Minsk]

UDC 551.510

[Abstract] Research on the information yield of optical characteristics is a very timely problem in solving inverse problems in light scattering. Carried out in the preliminary stage of model computations, it can be used in the optimal planning of optical experiments and guarantees reliability of the information obtained concerning the object. A vectorial method was developed for an analysis of the accuracy characteristics of solution of the inverse problem visualizing the availability of a joint ensemble of optical information and a priori evaluations of a stipulated part of the retrievable parameters. The derived relations are represented through sensitivity and correlation factors for optical signals in variations of the parameters and also are analyzed as a function of the quality of the a priori evaluations and limiting values of these factors. References: 10 Russian.

Model of Outgoing Short-Wave Radiation Over Pacific Ocean Based on 'Intercosmos-21' Satellite Data

917N0141D Tomsk OPTIKA ATMOSFERY in Russian Vol 4 No 1, Jan 91 pp 104-106

[Article by A. G. Laktionov, N. A. Lutseva, V. A. Mironenko and V. S. Suyetin, Applied Geophysics Institute imeni Academician Ye. K. Fedorov, USSR State Committee for Hydrometeorology and Environmental Monitoring, Moscow; Marine Hydrophysics Institute, Ukrainian Academy of Sciences, Sevastopol]

UDC 551.521

[Abstract] In a preceding article (OPTIKA ATMOSFERY, Vol 3, No 1, p 97, 1990) the authors gave the results of processing of brightness measurements of the "ocean-atmosphere" system over the Atlantic Ocean. Along these same lines this article gives the results of processing of similar measurements of spectral brightness in this system over the Equatorial Pacific. The measurements were made during 1981-1982 from the Intercosmos-21 artificial earth satellite with continuous sounding along the trajectory and orientation of the sighting axis to the nadir. The brightness of outgoing radiation of the "ocean-atmosphere" system was registered in 13 spectral channels in the visible spectral range. About 68 000 measurements over the Pacific Ocean 0-30°, which were grouped by seasons and six ranges of solar zenith angles (0-30, 30-60, 60-75, 75-80, 80-85, 85-90°), were statistically processed. For the Pacific Ocean region 0-30°N there were insignificant seasonal changes in the brightness spectra, for the most part not greater than 30 percent, and therefore all the collected data were subsequently processed regardless of season. On the basis of an analysis of these data a dependence of spectral brightness on atmospheric optical mass and wavelength in the spectral range 0.4-0.8 μm is proposed. These data are compared with a similar model for the Atlantic for the corresponding latitude zone. The relations derived in this and in the previous article can be regarded as statistical models of outgoing short-wave radiation over the equatorial regions of the Pacific and Atlantic Oceans. Figure 1; references: 2 Russian.

Extrapolating Atmospheric Lidar Sounding Data When Determining Slant Visibility

917N0141E Tomsk OPTIKA ATMOSFERY in Russian Vol 4 No 1, Jan 91 pp 107-112

[Article by V. A. Kovalev, Ye. Ye. Rybakov, M. V. Zakharyan and V. M. Ignatenko, Main Geophysical Observatory imeni A. I. Voyeykov, USSR State Committee for Hydrometeorology and Environmental Monitoring, Leningrad]

UDC 551.591

[Abstract] In order to estimate the slant range of visibility or the height of visual contact with an aircraft it is necessary to have information on how the mean extinction index or transmission coefficient changes with height. It was found that high-intensity landing strip lights become invisible when the optical depth τ of the atmospheric layer between the observed lights and the observer attains three or more (up to 10 or more at nighttime), whereas the effective range of the lidar corresponds to τ 1.5-2. An in-depth examination of this problem led to the proposal of several expressions allowing effective extrapolation of registered data over the necessary distances. The assumption of a nondependence between the mean extinction index measured in some atmospheric layer h on the slope to the horizon was investigated. Experimental results from long series of observations show that the heights obtained using lidar data are usually not dependent on the determined sounding angle, which confirms the feasibility of use and soundness of the extrapolation expressions proposed for lidar determination of nonhorizontal visibility. The degree of constancy of the measurement results with a change in the sounding angle serves as a test of the reliability of the results. Figures 4; references 12: 10 Russian, 2 Western.

Backscattering of Electromagnetic Waves on Anisotropic Turbulent Inhomogeneities

917N0126A Moscow IZVESTIYA AKADEMII NAUK SSSR: FIZIKA ATMOSFERY I OKEANA in Russian Vol 27 No 1, Jan 91 pp 67-75

[Article by A. S. Gurvich and A. I. Kon, Atmospheric Physics Institute, USSR Academy of Sciences]

UDC 551.55:551.52

[Abstract] There is much which still remains unclear in the theoretical description of the scattering of electromagnetic waves in a turbulent atmosphere. This study gives an analysis of the results of scattering theory with the use of a model of a Gaussian array proposed by A. I. Kon in INT. J. REMOTE SENSING, Vol 5, No 2, pp 257-262, 1984. The problem of scattering of electromagnetic waves on anisotropic turbulent inhomogeneities of permittivity was investigated in the Born approximation. Computations are simple and easily understandable final formulas are derived. The approach used is quite similar to that proposed by R. J. Doviak, et al., RADIO SCI. Vol 19, No 1, pp 325-336, 1984, but significant refinements have been made, especially with respect to clarification of the role of correlation scales and anisotropy of inhomogeneities situated in both the Fresnel and in the Fraunhofer zones of such arrays. Using the model of a Gaussian array a solution was obtained which can be used in the distant, as well as in the near zone of the array. No limiting conditions are imposed on the correlation scale of the inhomogeneities. The scattered power received by the array is essentially dependent on the relation between the anisotropy and the width of the array directional diagram, first increasing with an increase in anisotropy and then becoming saturated to some limiting level dependent on array parameters. Although the results apply to a specific model of an array with a Gaussian field distribution in the aperture, the conclusions would seem to be applicable for other types of arrays. Figure 1; references 13: 6 Russian, 7 Western.

Study of the Methods of Constructing Sea Bottom Geodesic Networks

917N0132A Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA in Russian No 5, Sep-Oct 90 pp 28-31

[Article by Chan Van Min, graduate student from the Socialist Republic of Vietnam at the Moscow Order of Lenin Institute of Engineers of Geodesy, Aerial Photography, and Cartography]

UDC 528.3

[Abstract] The highest level of accuracy is obtained when the network is constructed in the local system of coordinates of some reference triangle with measured sides. The axes of the network are defined according to this refrence triangle. The nonlinear equations for the linear spatial points of intersection are solved. A series of triangles was modeled to study the accuracy of transmission of coordinates by spatial linear points of intersection. Real measurement errors were modeled using a random number generator for six selections with an RMS error of 5 meters. The number of coordinate transmission (the number of joined sea bottom triangles) should not exceed five-six. Above this number errors grow rapidly. The effect of the number and position of refernce triangles was also studied. Increasing the number of reference triangles does not increase the accuracy of coordinate transmissions because errors enter into the parameters of coordinate conversion and distort them. A series which works outward froma central triangle is more suitable. Figure 1; tables 4; references 3 (Russian).

Theoretical Analysis of the Accuracy of a Method of Digital Processing for a Photoelectric Signal in Determining the Recording Times of Stars

917N0132B Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA in Russian No 5, Sep-Oct 90 pp 38-49

[Article by V. N. Baranov, docent and candidate of technical sciences, and A. P. Krasovskiy, graduate student at the Moscow Order of Lenin Institute of Engineers of Geodesy, Aerial Photography, and Cartography]

UDC 528.28-523.8

[Abstract] A combination of digital and analog techniques for processing photoelectric signals provided the most complete elimination of systematic error in recording the signal time and reduced random observational error. This theoretical study provides a comparative analysis of the accuracy of signal processing methods, including analysis by determining the maximum of the mutual-correlation fucntion. The "smoothed" method of signal processing contains systematic errors in recording the signal arrival times which are not linked with signal shape or filtering delay, but which are linked with noise parameters. The analysis tested the accuracy of determining the position of the energy center, the position of the autocorrelation function, signal error, and the effect of scatter. A digital processing algorithm which is based on maximum use of useful information is presented which provides signal filtering with no systematic error associated with filtering delay. This algorithm excludes the effect of field aberrations in the objective by using autocorrelation functions to determine the moment a star passes through the vertical of the instrument. Figures 4; references 6 (Russian).

Effect of Photography Altitude on the Static Parameters of an Aerial Photograph Image

917N0132C Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA in Russian No 5, Sep-Oct 90 (manuscript received 27 Jan 90) pp 75-82

[Article by V. V. Abrosimov, I. V. Almazov, V. N. Ovechkin, and A. F. Stetsenko, candidates of technical sciences at the Moscow Order of Lenin Institute of Engineers of Geodesy, Aerial Photography, and Cartography]

UDC 528.7

[Abstract] The altitude at which photographs are taken is one of the most important factors affecting image quality. This is due to the effect of atmospheric haze and the photogrpahic scale, which limits contrast and resolution. The effect of parameters of the aerial photographic process on image quality were analyzed. The resultant photographs were microphotometrically analyzed and the results of the analysis were statistically evaluated. The parameters used to best evaluate and characterize the effect on image quality were average image density, average RMS error in density, the signal amplitude, and informaiton content in bits. Photographs were taken at altitudes of 3000, 2000, 1000, and 500 meters. The goals of the analysis were to determine the parameters most sensitive to altitude and to compare predicted and actual results. The most sensitive parameters were dispersion, contrast and amplitude. One can confidently predict image contrast and resolution as a function of altitude for known illumination and method parameters. Figures 3; table 1; references 4 (Russian).

Use of Quaternion Algebra To Determine Coordinates and Orientation of an Aircraft From Aerial Photograph Data and Navigation System Data

917N0132D Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA in Russian No 5, Sep-Oct 90 pp 102-111

[Article by L. I. Aramanovich and L. V. Popov, candidates of technical sciences at the Moscow Order of Lenin Institute of Engineers of Geodesy, Aerial Photography, and Cartography (Aramanovich) and the Moscow Institute of Heat Engineering (Popov)]

UDC 528.7

[Abstract] This article examines the problem of determining the kinematic (linear and angular) parameters of an aircraft equipped with a platformless inertial navigation system. The equations of motion of the aircraft are integrated from some moment after motion has begun. When the navigation system is used in conjunction with aerial photography equipment, determination of these parameters is more accurate. Quaternions have been proposed for solving such photogrammetric problems. Systems of coordinates are set up and the relations between them are determined. Quaternions are used to develop equations to determine the orientation parameters of the aircraft. It is found that the use of only one aerial photograph with the navigation system is insufficient to obtain a single solution to the problem. The solution is given in analytical form. It is pointed out that this method may be easily implemented with a computer. There is no discussion of measurement error and its effect on accuracy. References 3 (Russian).

Study of Local Seismic Phenomena Using Maps and Aerial Photographs

917N0132E Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA in Russian No 5, Sep-Oct 90 pp 111-118

[Article by V. I. Mikhaylov, docent, candidate of geographical sciences at the Belorussian Polytechnical Institute; I. A. Tyashkevich, senior scientific staff member at the All-Union Scientific Research Institute for KAM [expansion not given]; A. M. Boborykin, senior scientific staff member at the Institute of Geophysics and Geochemistry of the Belorussian SSR Academy of Sciences]

UDC 528.7:550.348.425

[Abstract] Recently there has been great interest in predicting local seismic phenomena from maps, aerial photographs, and geodesic and geophysical studies in regions vastly changed by human activity, for example, the Soligorsk mining region. The region was considered aseismic until two large earthquakes occurred in 1978 and 1983. Other local seismic activity was noted in areas subjected to intense mining activity and large-scale earth excavation and movement. Aerial photographs of the region revealed a large number of lineaments. Details on the geological composition of the region are given. Comparison of tectonic maps and space photographs shows that the main faults of the area remanifest themselves in the newly created landscape. Studies are continuing to identify and isolate tectonically and structurally active zones which are seismically dangerous. Figures 4; references 4 (Russian).

Evaluation of Geometric Distortions of Sea Surface Parameters Obtained From Photographs

917N0132F Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA in Russian No 5, Sep-Oct 90 pp 119-127

[Article by M. P. Lapchinskaya, graduate student at hte Moscow Order of Lening Institute of Engineers in Geodesy, Aerial Photography, and Cartography]

UDC 528.711.1

[Abstract] Photographs of sea waves taken from low altitudes are commonly used to study the fine structure of the roughness of the sea surface. This roughness is primarily due to surface capillary and capillary-gravity waves. There must be great accuracy and detail in photographs of the sea surface relief and the contours of physical formations on the surface. This article examines a method of analyzing systematic errors in open sea surface relief in large-scale photographs taken from a fixed camera. A mathematical model is used which is a matrix of minimum and maximum distortions. One can unambiguously determine the accuracy of wave parameters and local physical formations making up the relief of the sea surface. As a result, one can correctly evaluate measurement information obtained in nontraditional photographs, correctly interpret processes captured in photographs, and choose the optimal size of the analysis window for a photograph. There is a detailed discussion of the determination of minimum and maximum distortions and manipulation of the resultant matrix of values, and error analysis. This method is promising not only in evaluating geometric distortions, but also in calculating statistical parameters of sea waves from photographs. Figure 1; tables 2; references 2 (Russian).

Allowance for Dependence of Ozone Absorption Sections on Temperature in Backscattering Method in Diagnosis of Earth's Atmosphere From Satellite

917N0089A Moscow TRUDY INSTITUTA EKSPERIMENTALNOY METEOROLOGII: OPTIKA ATMOSFERY in Russian No 22(144), 1990 pp 13-20

[Article by T. V. Kozina]

[Abstract] The accuracy in retrieving ozone layer parameters when making measurements from a satellite is dependent on the accuracy in computing backscattered radiation, but such computations are encumbered by a certain level of error. An effort was undertaken to evaluate this error. An approximate procedure is proposed which makes it possible to compute the effective absorption sections of ozone with an accuracy to about 0.2 percent and at the same time makes it possible to avoid time-consuming computations of the intensities of backscattered radiation involved in some traditional methods. Research on variations of the effective sections as a function of stipulated and a priori unknown atmospheric characteristics revealed that the temperature profile is the principal factor exerting an influence on variations of the effective section at a definite wavelength. Variations in the effective sections are determined by the dependence of the absorption sections on temperature and change in the altitude of the effectively scattering layer. At short wavelengths 2.55.7-287.7 nm the values of the effective sections can be considered identical for all model states of the atmosphere because their variations do not exceed 2 percent. The error in computing the intensity of backscattered radiation does not exceed 1 percent. Figures 3; references 5: 2 Russian, 3 Western.

Simulative Model of Spatial Distribution of Radiation of Clouds With Stochastically Uneven Boundary

917N0089B Moscow TRUDY INSTITUTA EKSPERIMENTALNOY METEOROLOGII: OPTIKA ATMOSFERY in Russian No 22(144), 1990 pp 20-23

[Article by V. G. Bulgakov and Ye. I. Ostrovskiy]

[Abstract] A simulative model of the spatial distribution of the radiation of clouds with a stochastically uneven boundary is described. In order to compute the radiation brightness field of clouds the observation plane was broken down into a series of squares. The coordinates of the centers of the squares coincided with the coordinates of points for which cloud thickness was determined. Within the limits of each square the thickness of the field was considered uniform. It was assumed that vertically the cloud cover has a moist-adiabatic gradient and that the albedo of single scattering and the scattering phase function do not change in the cloud volume. The Monte-Carlo method was used in computing the brightness of the characteristic radiation of such a cloud field in different directions with allowance for multiple scattering. The statistical characteristics of the brightness field were computed. Statistically homogeneous series of brightness values were formed. In each series the values were determined for directions having identical direction cosines but different coordinates. The mean brightnesses of the uneven surface are appreciably less than the brightness of a smooth surface. A decrease in mean brightness with an increase in zenith angle is related to a decrease in the radiation coefficient of even and uneven surfaces due to the influence of jscattering on the transfer of thermal radiation. The mean brightness of an uneven surface decreases more rapidly with an increase in nadir angle and at the same time there is an increase in dispersion and the coefficient of variability of brightness fluctuations. Figure 1; references; 4 Russian.

Underground Nuclear Shots for Improving Ecological Conditions

917N0128A Moscow PRIRODA in Russian No 2, Feb 91 pp 36-42

[Article by A. P. Vasilyev, N. K. Prikhodko and V. A. Simonenko]

[Text] Recently we have finally become aware how merciless we are relative to the environment, and accordingly, to ourselves, and still more, to our own children and grandchildren. The ingrained feeling of inexhaustibility of the natural wealth of "our immense Motherland" (most likely this well-worn phrase also has worked psychologically against a cautious attitude toward the environment), which has no basis whatsoever, has led to the unthinking, rapacious annihilation of these resources. Even now these accumulating and carefully hushed-up problems have arisen with increasing acuteness before an economically exhausted society, which does not know how to patch up the innumerable ecological "holes" which now exist. There is obviously a need to seek optimal environmental protection strategies which will make it possible to obtain a rapid and favorable effect with reasonable expenditures. One of such possibilities is the use of underground nuclear shots for improving the ecological situation. In our days this proposal may seem paradoxical, if not blasphemous. And nevertheless already available positive experience with the use of such technology and convincing, weighty arguments in its favor enable us to make an attempt to draw the attention of the public to it.

Reference will be to the industrial waste water discharged into the water bodies of the country, a high percentage (about 60 percent) of which does not meet sanitary norms.

In our country for the temporary (up to the next high water) storage of industrial waste waters, highly mineralized or containing toxic substances, extensive use is made of surface storage ponds or "white seas," as they are popularly called. This, to be sure, is the poorest of the methods for the decontamination of waste water. Each such pond occupies hundreds of hectares of land. Due to the constant evaporation of harmful substances the atmosphere in the neighborhood of the ponds is polluted. But the greatest danger is that in virtually all cases, despite the construction of protective screens of a clay layer or synthetic film, there is filtering of the industrial wastes into the ground water. The area of their pollution may attain 25 km^2. Cases are known of the breakdown of city water intakes for this reason. The elimination of such pollution of ground water is time consuming and expensive. For example, the cost of work on eliminating the causes and consequences of pollution of fresh water in the neighborhood of Aktyubinsk is estimated at 30-40 million rubles.

The best solution of the problem would be the development of waste-free technologies and the construction of purification structures capable of ensuring the necessary purity of air and water. However, it is known that it is necessary to pay for cleanness, and pay dearly: the cost of purification is comparable to the cost of production. It is also impossible to neglect such a factor as time. It requires the development of new production technologies and purification methods; it also is impossible to avoid time expenditures in the construction of new production facilities, in the modernization of old facilities and in supplying them with the required structures.

In many cases the pollution of air and water are unrelated and the problems of their purification can be solved independently, at least in some regions. Let's say that if it was possible by a simple and inexpensive method to cease water pollution for some time, all efforts and resources could be shifted to cleaning of the air, and then also be devoted to water. It is simplest to avoid the discharge of polluted waters by chemical plants into rivers and lakes and this could be accomplished by....

Deep Burial of Wastes

In order for this to be safe and reliable it is necessary to meet several very rigorous conditions, including the following.

1. The burial must be accomplished in strata constituting part of a stable geological formation and reliably isolated from artesian and surface ground water.

2. In these strata there must be a slow rate of water flow so that over a long period of time (hundreds of years) the wastes cannot penetrate into other geological formations and cause ground water pollution there.

These conditions are usually satisfied by worked-out deep-lying oil or gas pools. The very fact of prolonged existence of oil pools confirms the safety of filling of these lenses with liquid wastes. However, a rather great amount of oil (sometimes more than half the initial reserves) remains in a worked-out oil pool and the pumping of wastes into it may hinder our descendants from extracting these residues. It also must be remembered that a worked-out pool is not always located near a source of wastes and the laying of pipelines capable of withstanding their aggressive action is very expensive. In addition, the holes through which the wastes are pumped usually have a small intake capacity: only hundreds of cubic meters per day can be pumped through them, no more. Accordingly, for the burial of all waste waters of a single combine (and this is tens of thousands of cubic meters per day) it is necessary to drill many holes to a depth of 1.5-2.5 km, which is very costly. During the pumping of wastes the hole surface is rather rapidly clogged by the particles of the suspended matter present in them. Hence the need for the preliminary purification of wastes from solid impurities and their strong dilution by pure water. But even this, as indicated by experience, does not avoid a gradual decrease in the intake capacity by a factor of 5-10, which requires their frequent shutdown for scrubbing of the surface by different solvents.

But the most important consideration is that it is virtually impossible to pump industrial wastes chemically incompatible with stratum waters through ordinary holes: the sediments forming in this process clog the stratum pores and the hole ceases to accept wastes.

It must be noted that the intake capacity of holes drilled even at relatively short distances from one another may differ by tens or hundreds of times. A hole entering into a zone of natural fractures may accept 1000 m^3/day, at least during the first weeks of pumping, but a hole situated alongside it, even with pumping under a pressure of 100 atm, at times accepts only 10-100 m^3/day. Assurance of a high intake capacity (5000-6000 m^3/day), persisting over many years, is possible by setting off a relatively small (several kilotons)....

Nuclear Shot in a Hole

If a shot is set off at such a depth that it exerts no destructive effect at the surface, it is called a contained shot. All the nuclear shots set off in the territory of our country meet this condition. The requirements on nuclear shots used for peaceful purposes are still more rigorous, to wit: the destruction in the layers close to the shot site must not result in the entry of radioactive products into ground water or reach the surface.

A distinguishing feature of the processes accompanying strong shots is their similarity, that is, the coincidence of the characteristic parameters with identical relative distances and times. Accordingly, for nuclear shots the introduction of the reduced depth $h/E^{1/3}$, where h is usually measured in meters and the energy release E is usually measured in kilotons of TNT equivalent, is justified (See Footnote 1). As indicated by the results of many experiments, a shot at the depth h is a contained shot if its reduced depth is $h/E^{1/3}$ 120 $m/kt^{1/3}$. Tests in nuclear test ranges also are usually carried out at such reduced depths. Peaceful nuclear shots are carried out at far greater reduced depths. A project for drilling a so-called "enlarged" hole was proposed long ago (See Footnote 2) and two experimental industrial shots set off more than 15 years ago confirmed that this technology is applicable even in strata characterized by low permeability and filled with highly mineralized waters. However, what occurs in a nuclear shot? Without answering this question arguments in favor of the discussed technology may be without validation.

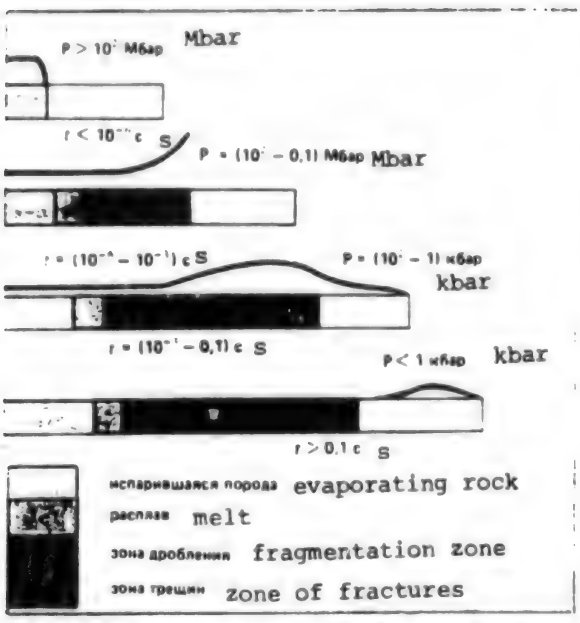
First, in a nuclear charge in a millionth of a second a pressure of millions of atmospheres develops at a temperature of millions of degrees. It is therefore not surprising that the capsule containing the nuclear charge and some of the surrounding ground evaporate. The density of the initially released energy is so great that its transfer into the dense medium surrounding the charge occurs primarily by radiative heat conductivity, that is, due to the mechanism operative in the hottest regions of stars. In this process increasingly newer layers of matter are affected, the energy density drops off, and beginning with some moment there is a change in the energy transfer regime to gas- dynamical in which a shock wave is the main mechanism. But in such a case as well the energy density in matter affected by movement is unusually high for natural terrestrial processes: at the wave front the matter experiences shock compression to densities exceeding the initial density by a factor of 4-5. In other words, such dense and solid substances as rocks behave as compressible gases. A rock experiencing the impact of such a strong shock wave evaporates, is fused, and at greater distances from the shot center is fragmented into sand and gravel.

With increasing distance of the shock wave from the center increasingly newer layers of matter are affected by movement, which results in shock wave attenuation: its amplitude (pressure and compression of matter at the front) and velocity decrease. At that time when its velocity is reduced to the velocity of longitudinal waves in the ambient rock a so-called "elastic precursor" appears ahead of the main shock wave front, which is then transformed into a seismic wave. In this case the shock wave front profile loses its jumplike character and becomes more gently sloping. Such a wave is usually called a loading wave. Behind it the rock mass is fragmented into blocks of different size; new fractures appear and already existing fractures expand.

The gas bubble formed by the evaporation products expands until its pressure becomes less than the lithostatic pressure of the ground. The cavity forming as a result of the shot at this time has a configuration close to spherical. At its boundary there is a layer of molten rock with a thickness about 10 cm which holds gases, including radioactive gases, within the cavity. Beyond this there is a zone (with a thickness 10-15 $m/kt^{1/3}$) of fragmented and fracturing matter. Depending on the specific properties of the rocks and the rock mass as a whole there may be significant deviations from the mentioned scales. However, the formation in the cavity of a condensed melt mixed with radioactive shot products occurs in any case, as a result of which the most dangerous radioactive products with high melting points are concentrated in the melt flowing onto the bottom of the cavity.

For peaceful purposes it is customary to use nuclear shots with a power of several kilotons. For these, depending on the shot depth and rock properties, the radius of the forming cavity is 7-10 $m/kt^{1/3}$ and the radius of the fracturing zone is up to 60 $m/kt^{1/3}$. As already noted, the phenomena accompanying a nuclear shot have a similarity: the changes in the rock mass are identical at distances with identical $r/E^{1/3}$ values. Thus, if the radius of the fragmentation zone is 25 $m/kt^{1/3}$, in a shot with E = 1 kt it is 25 m, but with E = 8 kt it is 50 m. Some deviation from this picture in the case of a contained shot may be attributable to gravity and ground parameters.

We have briefly outlined the picture of the mechanical processes accompanying a shot. However, in this picture a very important question has remained which in the



Destruction zones near center of underground nuclear shot. With increasing distance from the center of the shot the shock wave attenuates. First it evaporates the rock and then only melts it, thereafter only fragmenting it, but at great distances forms fractures. The strength and shape of the pressure impulse (heavy curve) change in this process. Finally, a seismic wave carries information on the shot to remote corners of the Earth.

minds of most people is associated primarily with nuclear shots, specifically, what behavior is exhibited by....

Radioactive Shot Products

As the gases are cooled the components with the highest melting points, and they also include radioactive fission fragments, precipitate onto the bottom of the cavity, forming a lens of melt in which the greater part (80-90 percent) of the radioactivity is concentrated. Its concentration can be still further increased if during shot preparation substances with a high melting point, sorbing different fission products, are located near the capsule with the nuclear charge. This procedure has been used successfully in actual practice. The melt lens is covered on top by a thick layer of rock flowing from the walls of the cavity and containing fewer fission products. Incidentally, the total activity of the shot is low. Whereas in a standard unit of an atomic reactor with an electrical power 1 GW about 1 ton of uranium is combusted annually and therefore about 1 ton of fragments is formed, in a typical peaceful shot only 200-600 g of fragments are formed, that is, less by a factor 1000. Scaled to 1 kt (for which approximately 60 g of fragments are formed) 500-700 tons of rock are melted, which favors natural self-burial and strong dilution of the radioactive products in a vitreous melt mass.

In a shot in rock salt a hermetic cavity is preserved even after cooling. In most rocks, sometimes a minute after the shot, and sometimes after 24 hours, the cavity collapses. Pieces of rock from the upper part of the cavity fall down, covering the melt lens in a thick layer. As a result, a collapse column is formed, which has a height approximately 4-6 cavity radii, from rock fragments with voids between them. In this process radioactive gases (krypton and xenon) which have not decomposed burst from the cavity along fractures. If there is a layer of plastic and impermeable rocks (salt, clay) above the fracturing zone, the radioactive gases remain in the shot zone and can neither enter the ground water nor reach the surface. Shots for peaceful purposes also are set off specifically under such geological conditions.

In order for the radioactive shot products not to be able to penetrate through the hole into the above-lying strata, in the hole, after the capsule with the nuclear charge has been lowered to a stipulated depth, a sealing plug, such as of cement, is formed. It is situated above the future collapse column and its length is from tens to hundreds of meters.

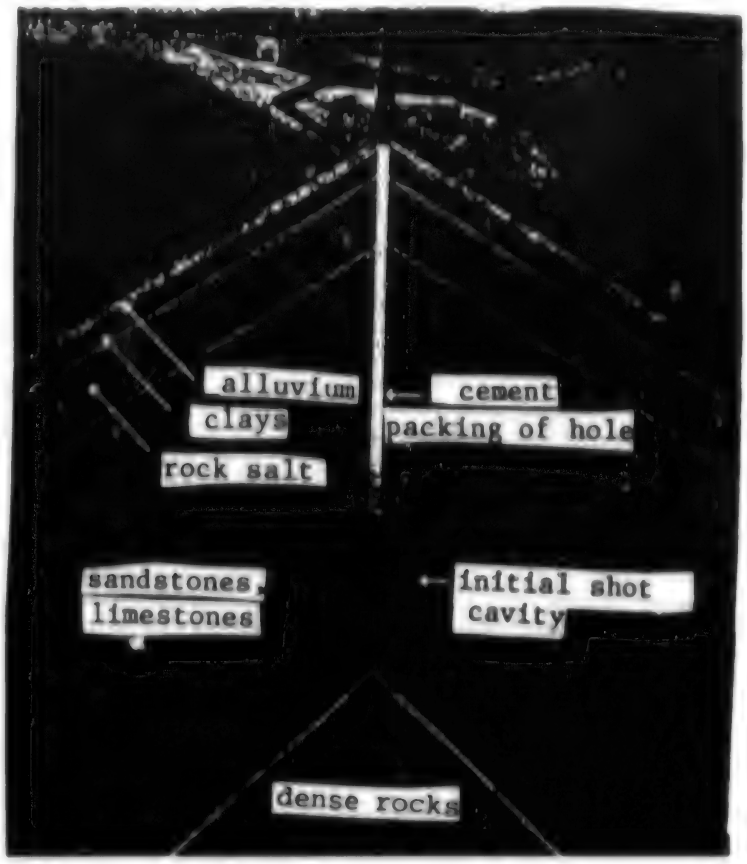
We have briefly cited the arguments pertaining to the safety and reliability of forming a cavity by a nuclear shot. It remains to discuss a last aspect, but one of more than a little importance....

Nuclear Shot and the Economy

Sometime after the shot (this is usually several months) the hole can be opened. By this time the short-lived isotopes of noble gases virtually completely lose their radioactivity. After removing the cement plug the hole is connected to the collapse column. This operation is considerably cheaper than the drilling of a new hole into the collapse column. The technology for restoring holes after a shot with assurance of their airtightness was perfected in the USSR with the formation of cavities in rock salt (See Footnote 3).

The wastes are pumped through the restored hole into the free space of the collapse column and then flow out through fractures into the stratum. If stratum waters are present in it (usually highly mineralized), with the pumping in of wastes they are driven from the hole. Since the size of the voids in the collapse column and the fractures emanating from it is quite great (tens of centimeters and even meters) fine mechanical particles do not clog them. Accordingly, concentrated wastes can be pumped in, which reduces the water expenditure tenfold.

The network of extended (up to 100-200 m from the column) fractures formed by the shot necessarily is joined to natural fractures. Accordingly, the hole is capable of accepting 5000-6000 m^3/day for many years. Assume, for example, that the thickness of the stratum into which pumping occurs at a rate 5000 m^3/day is 150 m, its porosity is 10 years and the rated time for hole operation is 30 years. It is easily calculated that during



Nuclear shot in hole. After the ending of drilling a casing is lowered into the hole and the cavity between it and the rock is cemented. The quality of the cementing is monitored by various geophysical methods. After lowering of the nuclear device a sealing plug is formed in the pipe, blocking the escape of radioactive gases into the upper layers.

this time wastes (and their volume is more than 50 million m^3) will fill a cylindrical layer of the stratum with a radius less than 1.5 km.

Thus, there is a possibility for sharply reducing the pollution of rivers and lakes by biologically harmful wastes in many places. This method has already been confirmed in the field and in the most immediate future can be rapidly employed in practical work. There are many places with favorable geological conditions in the country for its use. Thick strata of salt and clay, situated at a depth 1-1.5 km, reliably protect ground and artesian waters against the danger of pollution if the shots are set off at depths greater than 2 km. With a shot power 3-5 kt surface structures even near a hole are virtually undamaged, as is the drill rig with all its equipment which usually remains over the hole at the time of a shot.

One recalls a curious case illustrating a hypertrophied concept concerning nuclear shots. During one of the first experiments devoted to this problem, not long prior to the shot, the entire area, to the surprise of the physicists, was cluttered by large containers which had outlived their usefulness. After the shot their owners were very upset that they were all intact and had to be disposed of otherwise.

Upon completion of all the work at the surface nothing remains but the heads of the holes, to which lead the pipelines for the transport of wastes from the combines, and all the surrounding territory is suitable for it former economic use. Incidentally, since in the stratum the wastes are buried compactly, in the future, if it is necessary to use them as raw material, it would not be difficult to withdraw them through the same hole.

When highly mineralized waste water is pumped into an ordinary hole it can hold only tens of tons of particles of suspended matter, and this only in exceptional cases when the hole passes through an easily penetrated stratum-reservoir with an extensively developed natural network of fractures. A hole formed in connection with a nuclear shot, however, makes it possible to pump in waste waters containing four-five times more particles of suspended matter. If it is taken into account that its intake capacity is greater by a factor of 3-4, one such hole is capable of replacing at least 10 ordinary holes.

It is extremely important that it is possible to pump into the "enlarged" holes industrial wastes which are chemically incompatible with the stratum waters. The solid sediments forming during the interaction of the fluids are held in the voids of the collapse column (and this amounts to many thousands of cubic meters), as a result of which a cleared fluid enters the working stratum.

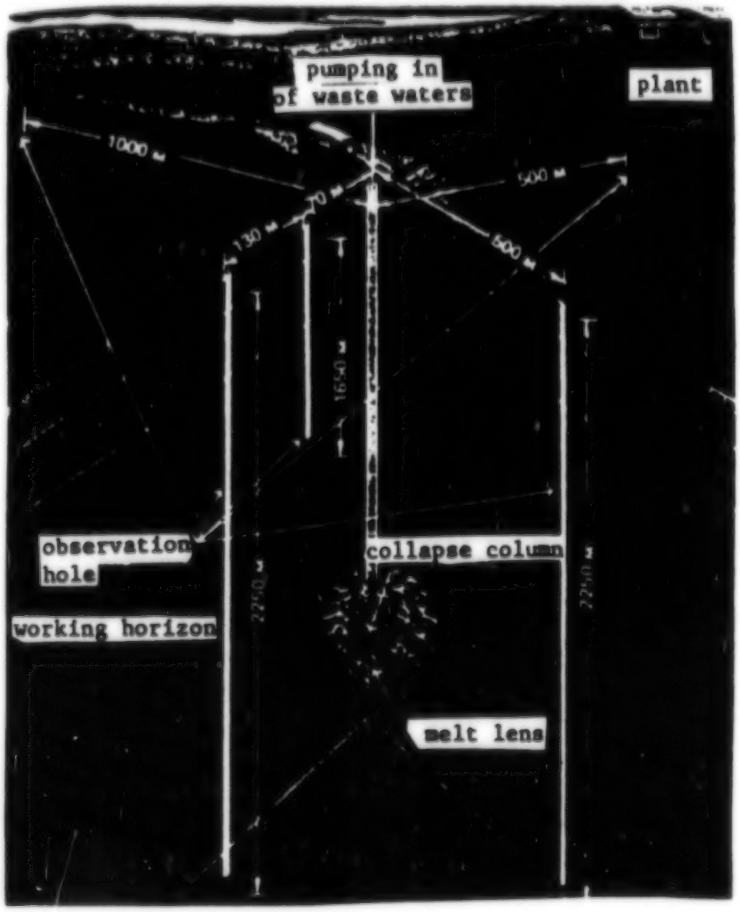
Taking into account that slightly diluted wastes can be pumped into the collapse column, for the burial of all liquid wastes of a large chemical combine it is sufficient to have three-four holes (one of which can be held in reserve).

According to the evaluations of ecologists, the loss from the dumping of waste waters into rivers and lakes, depending on their composition and place of dumping, is from 1 ruble to several tens of rubles per cubic meter of discharge. Accordingly, one hole makes it possible to prevent a loss of several million rubles per year and about 100 million rubles during the lifetime of the hole. However the construction of one injection hole and its opening after a shot, as well as observation holes and a pumping station, costs about 10 million rubles.

As already mentioned, in our country two small shots were set off for forming "enlarged" holes. Over the course of 13 years more than 20 million cubic meters of highly mineralized waste waters were pumped into one of them; in this process more than 1000 tons of solid sediments were introduced into the stratum together with the fluid. Over the course of five years more than 150,000 cubic meters of toxic runoff with a great quantity of suspended particles containing resinous substances, which have an exceptionally high capacity for clogging the pores of a reservoir-stratum, were pumped into the other. The burial of industrial wastes through ordinary holes is virtually impossible and for the time being there are no reliable methods for their purification.

The underground burial of harmful industrial wastes at these combines has now made it possible to prevent possible negative economic impact on the environment in the sum of about 100 million rubles.

Special economical small-caliber charges have been developed and repeatedly used for peaceful applications, so that the choice of the hole diameter is not determined by the charge but by the requirements on its intake capacity. As a result, the cost of the work is determined for the most part by expenditures on drilling of the holes.



Pumping of liquid wastes into collapse column formed by nuclear shot. After drilling out the sealing plug a pipe is lowered into the hole through which the waste waters are also pumped. Particles present in the waste waters remain in the voids of the collapse column and the fluid under pressure bursts out along the fractures. The observation holes drilled from different directions make it possible to monitor movement of the front of waste waters.

I would like to mention still another circumstance of more than a little importance. Safety considerations are of special importance for sources of highly concentrated energy. In developing nuclear charges for peaceful purposes measures have been adopted for excluding the accidental detonation of a nuclear charge under any conditions, including its falling from an aircraft. In addition, special features in the design structure of a charge make it possible to reduce the content of the most dangerous radioactive products.

With our communication we would like to draw the attention of different specialists, especially chemists, ecologists and economists, to the possibility of reducing the vulnerability of at least some ecologically threatened regions. This can be done rapidly, reliably, safely and without great expenditures.

In our country unique experience has been accumulated in setting off peaceful nuclear shots. They have been used in studying the deep structure of the Earth's crust and in quenching powerful gas gushers, in intensifying oil production and in forming underground cavities for the storage of petroleum products. (Unfortunately, the results of this work are better known abroad than in our own country.) A technology ensuring full radiation safety at all stages in the work nas been developed over the course of two decades and has been confirmed in practice. This technology includes rigorous requirements on choice of the place for setting off a shot and selecting its power, design of the hole and the nuclear device itself.

It is important not to lose what has been achieved. Incidentally, the use of uranium and plutonium from the warheads of missiles which have been disarmed for peaceful purposes would be both politically and economically advantageous. Such a charge would be virtually free of cost. Indeed, the storage of fissionable materials is both complex and costly and safety measures entail considerable expenditures. It is easier to annihilate a missile than a warhead. Therefore, such conversion is advantageous from all points of view. Physicists can assist in this. But only through the joint efforts of geologists, chemists, technologists, designers, economists and ecologists is it possible to select the most important threatened areas in the country where assistance to the environment impacted by anthropogenic factors is especially necessary.

We hope that such decisions will be adopted rapidly. And then very soon the wastes of at least one chemical combine would cease to flow into any innocent river.

Footnotes

1. 1 kt TNT equivalent is equal to 10^{12} cal. The term "power," rather than the more precise term "energy release," is used in the special and popular literature for shots, especially nuclear shots.

2. Atmomnyye vzryvy v mirnykh tselyakh (Atomic Shots for Peaceful Purposes), Moscow, 1970.

3. K. V. Myasnikov, Peaceful Nuclear Explosions, Vienna, IAEA, pp 201- 208, 1971.

Supplement: Biographical Data on Authors.

Albert Petrovich Vasilyev, candidate of physical and mathematical sciences, section head at the All-Union Scientific Research Institute for Technical Physics (Chelyabinsk-70). Field of scientific interests: nuclear physics and engineering, peaceful nuclear shots, including their ecological and economic aspects. Laureate of the USSR State Prize.

Nikolay Korneyevich Prikhodko, doctor of technical sciences, laboratory head at the All-Union Design-Planning and Scientific Research Institute for Industrial Technology. Principal scientific interests: research on physical processes in mining production with different methods for rock processing.

Vadim Aleksandrovich Simonenko, doctor of physical and mathematical sciences, professor, head of the theoretical department at the All-Union Scientific Research Institute for Technical Physics. Works in the field of study of physical and mechanical processes accompanying strong shots and development of theoretical and experimental methods for research on the properties of matter under extremal conditions. Laureate of the USSR State Prize.

Foreign Broadcast Information Service (FBIS) and Joint Publications Research Service (JPRS) publications contain political, military, economic, environmental, and sociological news, commentary, and other information, as well as scientific and technical data and reports. All information has been obtained from foreign radio and television broadcasts, news agency transmissions, newspapers, books, and periodicals. Items generally are processed from the first or best available sources. It should not be inferred that they have been disseminated only in the medium, in the language, or to the area indicated. Items from foreign language sources are translated; those from English-language sources are transcribed. Except for excluding certain diacritics, FBIS renders personal and place-names in accordance with the romanization systems approved for U.S. Government publications by the U.S. Board of Geographic Names.

Headlines, editorial reports, and material enclosed in brackets [ ] are supplied by FBIS/JPRS. Processing indicators such as [Text] or [Excerpts] in the first line of each item indicate how the information was processed from the original. Unfamiliar names rendered phonetically are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear from the original source but have been supplied as appropriate to the context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by the source. Passages in boldface or italics are as published.

SUBSCRIPTION/PROCUREMENT INFORMATION

The FBIS DAILY REPORT contains current news and information and is published Monday through Friday in eight volumes: China, East Europe, Soviet Union, East Asia, Near East & South Asia, Sub-Saharan Africa, Latin America, and West Europe. Supplements to the DAILY REPORTs may also be available periodically and will be distributed to regular DAILY REPORT subscribers. JPRS publications, which include approximately 50 regional, worldwide, and topical reports, generally contain less time-sensitive information and are published periodically.

Current DAILY REPORTs and JPRS publications are listed in *Government Reports Announcements* issued semimonthly by the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161 and the *Monthly Catalog of U.S. Government Publications* issued by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

The public may subscribe to either hardcover or microfiche versions of the DAILY REPORTs and JPRS publications through NTIS at the above address or by calling (703) 487-4630. Subscription rates will be provided by NTIS upon request. Subscriptions are available outside the United States from NTIS or appointed foreign dealers. New subscribers should expect a 30-day delay in receipt of the first issue.

U.S. Government offices may obtain subscriptions to the DAILY REPORTs or JPRS publications (hardcover or microfiche) at no charge through their sponsoring organizations. For additional information or assistance, call FBIS, (202) 338-6735,or write to P.O. Box 2604, Washington, D.C. 20013. Department of Defense consumers are required to submit requests through appropriate command validation channels to DIA, RTS-2C, Washington, D.C. 20301. (Telephone: (202) 373-3771, Autovon: 243-3771.)

Back issues or single copies of the DAILY REPORTs and JPRS publications are not available. Both the DAILY REPORTs and the JPRS publications are on file for public reference at the Library of Congress and at many Federal Depository Libraries. Reference copies may also be seen at many public and university libraries throughout the United States.

END OF FICHE

DATE FILMED

4 NOV 91